BODY COMPOSITION USING AIR DISPLACEMENT PLETHYSMOGRAPHY IN OBESE ADULTS: EFFECT OF ESTIMATED VERSUS MEASURED THORACIC GAS VOLUME

A Thesis
by
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Abstract

BODY COMPOSITION USING AIR DISPLACEMENT PLETHYSMOGRAPHY IN OBESE ADULTS: EFFECT OF ESTIMATED VERSUS MEASURED THORACIC GAS VOLUME

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Introduction: The Bod Pod uses air displacement plethysmography (ADP) to measure body volume (Dempster, 1995), and, with the measurement of body mass, is able to calculate body density for the analysis of body composition. However, total body density will be incorrectly estimated if the gas volume within the lungs at the time of the body volume measurement, termed thoracic gas volume (VTG), is measured inaccurately. The Bod Pod can account for VTG by using a prediction equation based on age and height (VTG_{pred}), or by direct plethysmographic measurement (VTG_{meas}). It is well established that obesity (OB) alters operational lung volumes at rest, which has the potential to increase the error associated with VTG_{pred} and the corresponding estimation of body composition. The purpose of this study was to examine the effect of VTG_{pred} and VTG_{meas} on estimates of body fat percentage (%BF) using the Bod Pod ($\%BF_{VTGpred}$, and $\%BF_{VTGmeas}$, respectively) as compared to %BF from dual X-ray absorptiometry (DXA) and a subcomponent estimation from DXA, trunk fat percentage, in normal weight (NW) and (OB) adults. Methods: Subjects came to the lab for a single visit and body composition testing was performed via Bod Pod and DXA. 15 NW (22.2 ± 1.7 $kg \cdot m^{-2}$) and 9 OB (32.1 ± 1.9 $kg \cdot m^{-2}$) adults (24 ± 6 yr) participated in the study. A mixed design analysis of variance was used to examine the effects of group and method on measurements of VTG and %BF. Results: The group by method interaction ($F_{1,22} = 3.017$, $p = 0.096$, $\eta^2 = 0.11$), the main effect for method ($F_{1,22} = 2.330$, $p = 0.141$, $\eta^2 = 0.09$), and the main effect for group ($F_{1,22} = 3.685$, $p = 0.068$, $\eta^2 = 0.14$), were not significant for VTG. The differences between VTG_{pred} and VTG_{meas} were not significantly related with body mass index (BMI) ($r = 0.33$, $p = 0.11$) but were with trunk fat percentage ($r = 0.47$, $p = 0.02$). There was a significant group by method interaction for %BF ($F_{2,44} = 10.060$, $p = 0.001$, $\eta^2 = 0.46$). Additionally, the main effect for group with %BF was significant ($F_{1,22} = 10.944$, $p = 0.003$, $\eta^2 = 0.51$). However, the main effect for method with %BF was not significant ($F_{2,44} = 0.663$, $p = 0.479$, $\eta^2 = 0.03$). The differences between VTG_{pred} and VTG_{meas} were significantly related with the differences between $\%BF_{VTGpred}$ and $\%BF_{VTGmeas}$ ($r = 0.92$, $p < 0.001$). In conclusion, although this study is underpowered, there appears to be a relationship between differences in VTG and error of %BF estimation. The differences of VTG is significantly related with the fat that is carried around the chest. DXA also appears to estimate %BF lower in normal weight adults but higher in obese adults compared to ADP.

Acknowledgments

I would like to say thank you to my committee members: Dr. Abigail Stickford and Dr. Jennifer Zwetsloot, for assisting me through this process. I would like to especially say thank you to Dr. Jonathon Stickford for mentoring me throughout my graduate career. He has guided me through very difficult circumstances, and I know that the skills and wisdom that he has shared with me will far exceed the scope of my academic career. I also would like to say thank you to the Exercise and Respiratory Physiology Lab for supporting me through my graduate career; the people I have worked with and the friends that I made have molded my passion for research and have furthered my inspiration to continue to move forward. I would like to say thank you to my friends and family for being there to support me and keep me from losing my mind. I will never forget the experiences that I have had here I believe it will truly mold me to be a better person. I have truly been inspired by Dr. Stickford's heart, and I won't forget the kind of person he is. I know that as I move on to other things the experiences that I have had here will shape my successful future.

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List of Abbreviations and Symbols

ADP	air displacement plethysmography
BMI	body mass index
$\%BF_{VTGmeas}$	body fat estimated air displacement plethysmography using measured thoracic gas volume.
$\%BF_{VTGpred}$	body fat estimates using air displacement plethysmography using predicted thoracic gas volume
$\%BF_{DXA}$	total body fat estimates using dual X-ray absorptiometry
DXA	dual X-ray absorptiometry
η^2	Eta-squared
BV_{raw}	raw measured body volume
BV_{corr}	corrected body volume
cmH_2O	centimeters of water
EELV	end-expiratory lung volume
EILV	end-inspiratory lung volume
ERV	expiratory reserve volume
FM	fat mass
FFM	fat free mass
$FM_{VTGmeas}$	fat mass from air displacement plethysmography using measured thoracic gas volume.
$FM_{VTGpred}$	fat mass from air displacement plethysmography using predicted thoracic gas volume.

$FFM_{VTGmeas}$	fat free mass from air displacement plethysmography using measured thoracic gas volume.
$FFM_{VTGpred}$	fat free mass from air displacement plethysmography using predicted thoracic gas volume.
FEV_1	forced expiratory volume in one second
FRC	functional residual capacity
FVC	forced vital capacity
Ht	height
IC	inspiratory capacity
IRV	inspiratory reserve volume
kg	kilogram
L	liters
min	minutes
NHANES	National Health and Nutrition Examination Survey
NW	normal weight
OB	obese
OR_a	adjusted odds ratio
r	Pearson's correlation
RV	residual volume
s	seconds
SAA	surface area artifact
SD	standard deviation
SEE	standard error of estimate

TLC	total lung capacity
TBW	total body water
US	United States
VC	vital capacity
VTG	thoracic gas volume
VTG_{pred}	predicted thoracic gas volume
VTG_{meas}	measured thoracic gas volume
V_T	tidal volume
Wt	weight
yr	years

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Introduction

Overview

Obesity is generally defined as an excess amount of adipose tissue (Gadde, 2018). A more phenotypical trait of obesity is the large variation of body fat distribution relative to the total body mass (Thomas, 2012). While not a direct measure of body fat, body mass index (BMI) provides an index of fatness by scaling body weight relative to height. Adults with a BMI ≥30 $kg \cdot m^{-2}$ are considered obese, which is calculated using the following equation:

$$BMI = mass(kg) \bullet height(cm)^{-2} \tag{1}$$

The prevalence of obesity has increased substantially across the United States (US) over the past 20 years, with over 100 million adults currently classified as obese (Hales, 2017). The growing prevalence of obesity has reached epidemic status resulting in over 147 billion dollars annually in medical expenses (Finkelstein, 2009). The relationship between all-cause mortality and body weight is not entirely clear (Ades, 2010); however, those who are obese are known to be at higher risk for a variety of health conditions such as cardiovascular disease, type 2 diabetes, and respiratory complications (Bastien, 2014; Beuther, 2006; Hubert, 1983). Thus, it is imperative that obese individuals lose weight in order to reduce the potential negative health consequences and ease the substantial economic burden.

A variety of methods exist to help individuals lose weight, including: changes in dietary behaviors, engaging in regular exercise routine, and participating in pharmacological, and or surgical treatments (Santos, 2017). In 2017, nearly 44% of US adults engaged in at least one weight loss strategy (Santos, 2017). Measuring changes in body composition is a useful method to track the effectiveness and progress in those trying to lose weight. However, obesity can sometimes prove to be an obstacle in the accurate estimation of body composition because equipment used for measurement cannot always accommodate larger body sizes, and some assumptions that these devices make based on normal populations do not apply to obese individuals.

Common methods of estimating body composition aim to measure the amount of fat mass (FM) versus fat free mass (FFM) that make up the body (Fields, 2002; Lee, 2008). This two-part approach is known as the two-compartment model, and uses the densitometric method by categorizing body composition based on the inherently different densities of FM and FFM. Air displacement plethysmography (ADP) is a favored method of body composition estimation in many populations due to its relative ease of use, and ability to comfortably accommodate larger individuals. Dual X-ray absorptiometry (DXA) further separates FFM into bone and lean tissue constituents while still accounting for FM. Thus, DXA is considered a more robust measure of estimating body composition compared with ADP because it can separate tissues into three, as opposed to two compartments.

Air Displacement Plethysmography

Use of ADP in obese individuals is practical because it requires little technical skill, and can accommodate larger individuals (Bernhard, 2016). By measuring body mass and volume, density can be determined. While mass is typically measured by a scale, ADP measures volume by the displacement of air. Subsequently, the calculated density is used to estimate percent body fat (%BF). To more precisely estimate body composition based on volume, factors that have the potential to alter body volume measurements are important to consider. For air displacement devices, the volume of gas within the thoracic cavity, termed thoracic gas volume (VTG), plays an important role in the accuracy of body volume measurements.

The ADP device can predict or measure average lung volumes during tidal breathing within the chamber. In normal weight adults, the predicted and measured VTG (VTG_{pred} and VTG_{meas} respectively) are similar to one another, along with the respective estimates of %BF using VTG_{pred} and VTG_{meas} (D. Wagner, 2015). Yet, there still are gaps in knowledge with how these two methods compare in obese adults, whose lung volumes at rest are different than normal weight adults of the same height and age. Wagner (2015) analyzed the agreement of these methods in athletes and observed that the subjects with the smallest VTG had their VTG overestimated and those with a higher VTG had their VTG underestimated. This may suggest that obese adults who demonstrate lower operational lung volumes at rest, may have less consistent findings between VTG_{pred} and VTG_{meas}.

Dual X-ray Absorptiometry

DXA is a method of measuring body composition using photon absorptiometry. The device relies on the core concept that X-ray light will be attenuated as a function of the tissue it passes through (McCrory, 1998b; Pietrobelli, 1996). DXA is a popular tool that often can be found in many research and clinical settings, making it useful in comparing body composition in epidemiological studies (Cornier et al., 2011). While DXA can provide more robust measurements to estimate body composition, similar to ADP, it is still limited by the assumptions regarding the density of human tissue. The benefit of DXA in contrast to ADP is that measures for estimating %BF are independent of VTG. DXA cannot be substituted for a gold standard such as the four-compartment model, but its broadened use in clinical and research practice serves as an anchor to compare other accessible methods of body composition measurement.

Summary

Statement of the Problem

It is unknown whether estimation VTG by VTG_{pred} will be different in obese adults, and if those potential differences will contribute to greater error in the %BF estimations compared to VTG_{meas} in obese adults compared to normal weight adults. By understanding the impact that obesity may have on %BF estimates, more care can be taken by researchers and clinicians to ensure the most reliable techniques are being implemented for estimating %BF by ADP in an obese population.

Purpose of the Study

The primary purpose of the study was twofold: 1) to examine VTG_{pred} and VTG_{meas} in obese (OB) and normal weight (NW) adults and 2) to examine the $\%BF_{VTGpred}$ and $\%BF_{VTGmeas}$ in OB and NW adults. A secondary purpose was to compare %BF estimates obtained via Bod Pod with an estimate obtained via DXA, a lung volume independent technique.

Delimitations

The study was delimited by the following:

1. Males and females between the ages of 18 and 45 years participated.

2. All doors to the room with Bod Pod remained closed during calibration and testing in an effort to minimize air flow (Lowry & Tomiyama, 2015).
3. The Bod Pod and DXA devices were calibrated the day of each visit.
4. All subjects wore minimal skin tight garments along with a swim cap in an effort to minimize surface area artifact (SAA) for the Bod Pod.
5. All subjects wore the same garments for DXA as for the Bod Pod to maintain consistency across methods of measurement.
6. Height of the subjects was measured to the nearest centimeter.
7. Weight of the subjects was measured to the nearest kilogram.
8. All of the subjects voided their bladder before the test
9. All of the subjects completed tests back to back
10. All of the subjects refrained from exercise in the two hours prior to testing.
11. All of the subjects fasted two hours before the visit.

Limitations

Interpretation of the results should consider the following limitations:

1. All of the subjects were from the same geographical area.
2. Some subjects had facial hair and/or body hair not accounted for with skintight gear.
3. Skintight garments will make up some of the measured mass of the individual.
4. The Bod Pod assumes uniform density of FFM.

Research Question

The primary research question was to examine the potential differences in VTG_{pred}, and VTG_{meas}, and the respective calculations of %BF in OB compared with NW adults. The secondary research question was to examine %BF via ADP ($\%BF_{VTGpred}$, $\%BF_{VTGmeas}$) with %BF from DXA ($\%BF_{DXA}$). The following research questions were addressed:

1. Are VTG_{pred} and VTG_{meas} significantly different in OB and in NW adults?
2. Are the differences between VTG_{pred} and VTG_{meas} significantly associated with BMI?
3. Are $\%BF_{VTGpred}$ and $\%BF_{VTGmeas}$ significantly different in OB and NW adults?
4. Are $\%BF_{VTGpred}$, $\%BF_{VTGmeas}$, and $\%BF_{DXA}$ significantly different in OB and NW adults?
5. Are the differences between VTG_{pred} and VTG_{meas} significantly related with the differences between $\%BF_{VTGpred}$ and $\%BF_{VTGmeas}$ in OB and NW adults?

Hypotheses

The primary hypotheses of the study are:

1. VTG_{pred} and VTG_{meas} will be significantly different in OB adults but not in NW adults.
2. The differences between VTG_{pred} and VTG_{meas} will be significantly associated with BMI.
3. $\%BF_{VTGpred}$ and $\%BF_{VTGmeas}$ will be significantly different in OB adults but not in NW adults.

4. $\%BF_{VTGpred}$, $\%BF_{VTGmeas}$, and $\%BF_{DXA}$ will be similar in NW adults; $\%BF_{VTGpred}$, $\%BF_{VTGmeas}$, and $\%BF_{DXA}$ will be significantly different in OB adults, with $\%BF_{VTGmeas}$ similar to $\%BF_{DXA}$ in OB adults.
5. The differences between VTG_{pred} and VTG_{meas} will be associated with the differences between $\%BF_{VTGpred}$ and $\%BF_{VTGmeas}$ in OB and NW adults.

Definition of Terms

Obesity- Excess amount of body weight for a given height (Wellens, 1994).

Air Displacement Plethysmography- The measure of volume via the displacement of air (Aitkens, 1995).

DXA- Machine that measures the attenuation of high and low energies of X-rays passing through the body to evaluate body composition (Toombs, 2012).

Body Mass Index- A ratio of one’s mass to their height squared (Wellens, 1994).

Thoracic Gas Volume- Volume of air within the lungs at the end of a tidal breath (D. Wagner, 2015).

Forced Vital capacity- Maximal volume of air that can be exhaled after a forced exhalation (Robert Crapo, 1994)

Forced Expiratory Volume in 1 second- Maximal volume of air exhaled, after a maximal inhalation, in the first second of a forced exhalation (Robert Crapo, 1994).

Literature Review

Obesity is an Epidemic

Obesity is defined as having an excess accumulation of body mass in respect to one's height. It is increasingly prevalent in affluent societies that are living in dietary excess (Kopelman, 2000). Within the US alone, over one-third of the population is now considered to be overweight. The prevalence of obesity has increased drastically over the past 50 years (Kuczmarski, 1994; Ogden, 2015).

The National Health and Nutrition Examination Survey (NHANES) reported in 2017, that the prevalence of obese adults over 20 yr has reached 39.6%. That percentage applied to national health estimates in 2017 from the United States Census Bureau (*2017 National Population Projections Datasets*, 2018), projected 96 million adults 20 yr or older in the United States would be considered OB. That is not even considering that over 18% of the youth (ages 2-19 yr) are now OB with significantly increasing trends (Hales, 2017). Obesity has become so prevalent, that it is now affecting the economic health of the nation.

The economic cost of obesity is a public health concern. There is a link between obesity, and medical spending. Those who are obese are at an increased risk for cardiovascular disease, type 2 Diabetes, along with various respiratory complications (Bastien, 2013; Chan, 1994; Zammit, 2010). As of 2008, aggregate medical cost of obesity was estimated to be up to 147 billion dollars, representing 9.1% of all annual medical spending (Finkelstein, 2009).

In epidemiological studies the most common tool for measurement is BMI.
It is a useful method to classify weight status amongst large populations and make valuable comparisons within and between populations. BMI classification is also advantageous in

identifying large groups who are at higher risk of morbidity and mortality. The idea behind the BMI formula is based on the assumption that the varying weight of people of the same height is generally due to changes in FM (Kopelman, 2000). The current standard of the cut-off points for the classification of those overweight were suggested by the world health organization (WHO) experts. They identified two different grades of being overweight. These two levels are described as preobese, and obese, which can be subdivided into obese class I, II, and III in order of least to most severe. The cut-off points for each are 25.0-29.9 $kg \cdot m^{-2}$, 30.0-34.9 $kg \cdot m^{-2}$ 35.0-39.9 $kg \cdot m^{-2}$, and ≥ 40 $kg \cdot m^{-2}$ respectively (Wellens, 1994).

While there are high associations between increases of BMI and increased risk for disease, the consequence of obesity is more directly related to fat tissue, and the overall distribution of that fat tissue in the body (Kopelman, 2000). For example, an increase in FM will increase the total amount of blood volume, and subsequent amount of oxygen that the body consumes increasing cardiac output, placing added stress on the heart (Bastien, 2013). A study done by Krotkiewski et. al., highlighted the differences in regional distribution of adipose tissue within males and females. Men predominately have more abdominal adiposity, while women have more peripheral distribution of fat (gluteal and femoral regions). Males were more likely to indicate signs of metabolic disease, such as higher levels of fasting glucose and triglycerides. Females with regional adipose tissue similar to the male group showed similar increases in metabolic disruption (Krotkiewski, 1983). With increases in FM, there are uniform increases of visceral fat. The increase of this intra-abdominal visceral adipose tissue (upper body obesity) that is common in men, contributes to organ and hormone dysfunction. Respiratory complications arise from the distribution of fat that accumulates around the thoracic cage, and abdomen (Kopelman, 2000; Krotkiewski, 1983)

Respiratory Complications in Obesity

Increases of BMI are associated with decreases in lung function and lung volumes (Koenig, 2001a; Mejbel, 2016; Zammit, 2010). A case control study recruiting 100 individuals ages 18-45 yr found significant spirometric reduction in the overweight males and females. Significant negative correlations were observed with %BF and forced vital capacity in 1 second (FEV1) (-0.772 $p < 0.001$), and with %BF and forced vital capacity (FVC) (-0.869 $p < 0.001$) (Mejbel, 2016). This decrease in lung function and lung volume is, in part, due to the accumulation of fat within the anterior chest and abdominal wall (D'Angelo, 1999; Kopelman, 2000). A cross-sectional population based study was carried out with a sample of 121,454 men and women (45.7 ± 12.3 yr) in Paris to investigate the risk of lung function based on characteristics of metabolic syndrome. In their findings those with larger waist circumferences were at higher odds for impaired lung function (Leone, 2009).

Respiratory Compliance

Obesity contributes to a large load being placed on the respiratory muscles. The respiratory muscles have to compensate for the extra load contributed by excess fat in order for alveolar ventilation to be maintained (Sampson, 1983). A prevailing atypical lung volume measurement across multiple studies involving obese subjects is a decrease in expiratory reserve volume (ERV) (Koenig, 2001b; Littleton, 2012). These evident decreases in lung function can be explained in part by the lengthened duration of respiratory muscle activation during exhalation, and the effect of upper adipose tissue on respiratory mechanics. Whereas adipose tissue will compress around the thoracic cage, diaphragm, and lungs, negatively affecting total respiratory compliance. Compliance can be defined as the ratio of change in pressure to changes in volume (Suratt, 1984). A decreased compliance of the respiratory system would indicate that a given change in pressure would change the volume of gas in the lungs less (Suratt, 1984). Total respiratory compliance is equal to the sum of chest wall compliance and lung compliance (Harris, 2005). A decreased total respiratory compliance in obesity is thought to have dynamic contributions from each of these parts. A significant decrease in the pressure volume curve slop indicated in Figure 1, relates directly with a decrease in total respiratory compliance.

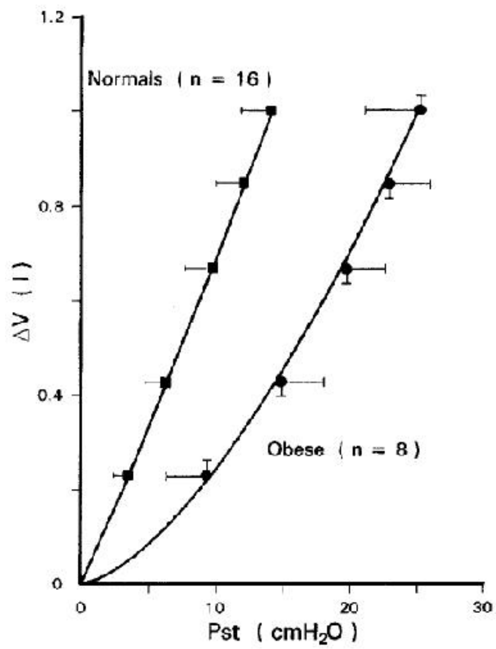

Figure 1. The effect of obesity on the pressure volume curve; Pst, static pressure of the total respiratory system; ΔV, change of volume (Harris, 2005).

How is Body Composition Measured?

The term body composition encapsulates multiple subunits of differentiated tissues and organs, such that the total body mass will equal the sum of these individual parts. Ideally, each constituent, or compartment, needs to be taken into consideration to accurately account for body composition. Given the complexity of the human body, it proves difficult to itemize, and quantify each individual piece of this larger puzzle (Wang, 1999; Ward, 2018). With technological advances, more of these constituents can be quantified for application to better describe the total body composition. More refined methods are not cost effective and require more training to use. As a result, the two compartment model approach to measurement is popular.

The methods to measure body composition have greatly changed over the years. There are multiple techniques used to electronically estimate body fat: bio-electrical impedance (Bernhard, 2016), DXA, quantitative human tomography, ADP, magnetic resonance imaging, quantitative magnetic resonance, 3-dimensional photonic scanners, and positron emission tomography (Lee, 2008). A relatively more practical method of quantifying body composition is through ADP, this method is more mobile, and reduces subject and technician error (Dempster, 1995). The derived density of the whole body can be used to estimate a two-compartment model of body composition (FM and FFM) (Siri, 1961). The density of the human body can be derived by the relation between its' mass and volume (2**)**

$$Density = \ mass\,(kg)/volume(mL) \tag{2}$$

While mass is easily measured, the volume of the body is more difficult to determine. Body volume is not uniform throughout; cavities within the lungs and gastrointestinal tract are unable to be detected through superficial measurements of volume. Heat leaving the body also has potential to alter pressure measurements during ADP. Not correcting for the volume of air within your body will greatly affect the subsequent calculations of density. Methods for controlling these variables usually are constringent, and can sometimes be a deterrent for subject participation, especially when measurements are conducted in water. New technology has opened different avenues for collecting accurate measurements that also take less effort for the subject, and leave less room for technician error. The use of Bod Pod for plethysmography has grown in popularity because it can provide accurate measurement of density and is a convenient tool for technicians and patients to use.

The Bod Pod utilizes ADP to indirectly measure body volume. When an individual sits inside a closed chamber, the amount of air within said chamber will be displaced because of the addition of a new volume inside the chamber. The volume of air displaced will be equal to the volume of the body entering the closed system. The Bod Pod measures the pressure change initiated by a volume perturbing diaphragm while the subject is within the chamber (Aitkens, 1995). Past methods of ADP required isothermal conditions to measure volume by pressure, this applies the basic principles of Boyle's law that states pressure and volume have an inverse relationship, such that as volume increases, pressure will decrease, given that temperature does not change. Keeping thermal conditions constant during body density measurement proves to be a laborious task (Fields, 2002). The Bod Pod makes use of both Boyle's gas law and Poisson's law, which allows for air to expand and compress within the closed chamber and still have volume and pressures accurately measured. This technique is useful to account for the increase in temperature that introducing a human subject to the chamber will cause. As a result, being able to compensate for changes in temperature, measurements can be assessed with less effort (Dempster, 1995; D. R. Wagner, 2000).

The Bod Pod consist of one structure with two coinciding chambers (front and rear) which sizes are about 450 L and 300 L respectively. The front chamber is where the subject is housed. The second chamber is separated by the molded seat in which the subject sits on during the testing. The rear chamber houses electronics, pressure transducers, breathing circuits, valves and the diaphragm that initiates volume perturbations (Figure 1) (Aitkens, 1995). The relations of volume and pressure are applied to measurement when the subject has been placed in the front chamber, and the door has been sealed by multiple electromagnets. A diaphragm in the rear chamber oscillates in the positive and negative direction at a magnitude of about 350 mL inducing pressure changes of about 1 cmH_2O within the system (Aitkens, 1995). Volume will have a linear relationship with these pressure changes.

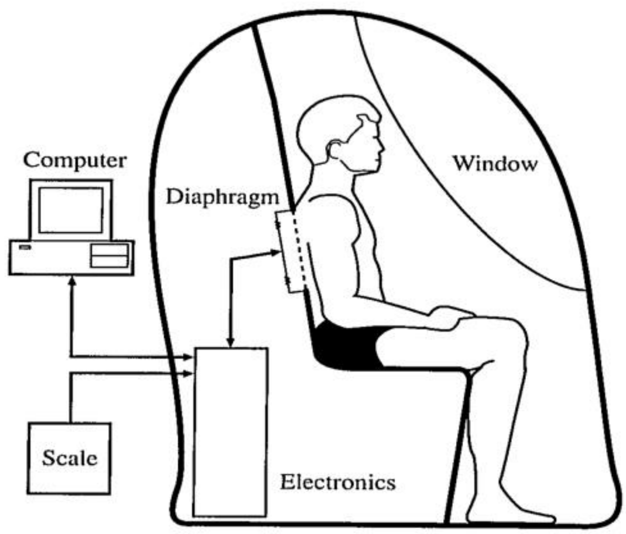

Figure 2. Diagrammatic representation of the main components of the Bod Pod system from the Official Journal of American College of Sports Medicine (Aitkens, 1995).

In order to accurately measure body volume, it is important to account for factors such as clothing, SAA, and lung volumes (Aitkens, 1995; Fields, 2002; Higgens, 2001; McCrory, 1998a). The raw body volume (BV_{raw}) that is measured using pressure-volume relationships is corrected taking into consideration SAA and VTG. Effects of clothing and hair are mitigated by the standard use of minimal skin-tight gear and a swim cap. Other bodily hair may be worth noting in error of measurements (Higgens, 2001). Body surface area, given a person's height and weight is estimated using the Dubois formula (Bois, 1916). The estimated body surface area is then multiplied by a constant that defines the effect surface area has on volume measurement. The product of these factors gives a correction for SAA. VTG is either predicted with an estimation equation based on age, and height, or directly measured with plethysmographic techniques. The formula to determine body volume includes these factors:

$$BV_{corr} = BV_{raw} - SAA + 40\%VTG \tag{3}$$

Where BV_{corr} is corrected body volume, BV_{raw} is raw measurement of body volume based from Boyle's law, and 40% of VTG is considered because air within the lungs is considered isothermal and is 40% more compressible than adiabatic air within the chamber. All values are expressed in liters (Dempster, 1995; McCrory, 1998a).

Thoracic gas volume may be obtained from the Bod Pod by an estimation equation or through an actual lung volume measurement within the Bod Pod. VTG_{pred} is calculated for the Bod Pod as:

$$VTG_{pred} = FRC + 0.5\, Vt \tag{4}$$

Where functional residual capacity (FRC) is the volume of air within the lungs at the end of a passive breath. During normal breathing, the amount of air moving in and out of the lungs is tidal volume (V_t). The mid-point of an exhalation is measured, the 50% of measured V_t the average volume of air being displaced during normal breathing. The following equations developed by (R. Crapo, Morris, Clayton, & Nixon, 1982), are how FRC and VTG were estimated accounting for age and height. In order to develop prediction equations, multiple linear regressions of each lung volume were generated against combinations of the independent variables height, age, and weight SAA. Regression equations were also calculated using transformations of both the independent and dependent variables. For each equation, the standard of the estimate and the correlation coefficient were calculated. For the equations reported, residuals (measured value minus predicted value) were graphically analyzed by comparing the residual values with the independent variables and the predicted dependent variables.

Bod Pod is a type of body density measurement. There is a wide variations of body composition values dependent of the methods of measurement that is utlized, although some of this difference may be accounted for by biological variability and technical precision, it is widely unknown as to why these values are different (Fields, 2002).

Average Thoracic Gas Volume

ADP can measure body volumes, and VTG. The value for VTG continuously changes during the act of breathing (inhalation, exhalation). FRC is described as the volume of gas in air at the end of a passive exhalation. The amount of volume in the lungs during resting, tidal breathing ranges from FRC to volume at the end of an inhalation, end inspiratory lung volume (EILV) (Wanger, 2005). Advanced body composition measurements devices such as ADP estimate VTG using a regression equation created from healthy, non-smoking adults (R. Crapo et al., 1982). Accounting for the lung volumes better depicts the density of an individual after pressure displacement (Aitkens, 1995). Individuals' who's lung volumes are lower relative to others that are their same sex, age, and height are inaccurately depicted by these regression equations (Minderico, 2008; D. Wagner, 2015). For example, an obese individual will have a smaller FRC and subsequent ERV; the estimated equation that is based on age and height (R. Crapo et al., 1982), will not account for smaller VTG due to added adiposity. With this overestimation of FRC in obese individuals, ADP may estimate the volume of during the measurement incorrectly, and therefore the measured %BF would potentially be different.

VTG Measurement

The technique the Bod Pod uses to measure thoracic gas volume is based on the relation between pressure and volume while temperature is constant (Dempster, 1995). Boyle's law states that pressure and volume have an inverse relationship (**5**)

$$P_1V_1 = P_2V_2 \tag{5}$$

where P_1 is the pressure at FRC, V_1 is FRC, and P_2 is the pressure at the end of a pant and V_2 is the acquired lung volumes (Dubois, 1956; West, 1999). When the subject initially comes onto the mouthpiece, lung volumes are unknown, without any flow the pressure of alveolar gas and atmospheric pressure are the same. This is only true if the glottis is open and the cheeks are held rigid (so they do not puff) If the subject was to voluntarily expire, which would compress the gas, the difference in pressure would describe the changing lung volumes during panting at the time of measurement, according to Boyle's law. One way to measure lung volume is to have the subject inhale after the end of a normal expiration when the closed system has been occluded and perform a panting maneuver; this is the method the Bod Pod uses to measure VTG. This method is usually preferred because it allows for retracing of the changes in volume and has less change in intrathoracic pressure (Dubois, 1956).

Dual Energy X-ray Absorptiometry

In the study of body composition, DXA is a common device utilized in research (Pietrobelli, 1996). It is often used to diagnose osteoporosis, osteopenia, and other bone diseases (Laskey, 1996; Sartoris, 1989; Toombs, 2012). Generally speaking, DXA machines measure the attenuation of high and low energies of X-rays passing through the body. The X-rays are comprised of photon particles that are transmitted via electromagnetic energy. Attenuation of the X-ray is dependent on the intensity of the photon particles, and the density of the substrate it is passing through. For example, bone mineral (higher density) will have larger decreases of photon intensity compared to soft tissue (lower density) as it passes through the body (Pietrobelli, 1996). To determine bone mineral density, DXA software assumes a compartment model where the body is divided into bone mineral, and soft tissue (skin, fat, muscles, fluids etc.) (Toombs, 2012). To differentiate between these two compartments, two intensities of X-rays are used. Low density material attenuates the X-ray less because more photon particles can pass through the body, the opposite is true for denser bone mineral. These relationships are used to differentiate between bone mineral density, fat mass, and fat free mass (Pietrobelli, 1996). The Hologic manufactured DXA performs its measurements by scanning the body with X-rays that are rapidly switching from high and low intensities sourced from below the scanning table (Laskey, 1996). The attenuated photons are detected and measured above the subject being scanned (Figure 2). Although the main purpose of the DXA has been in quantifying bone density, due to advances in detecting changes of photon intensity as it is attenuated through the body, resolution of images has improved (Toombs, 2012). With improved resolution DXA has also gained the ability to delineate between other subdivisions of body composition such as FM and FFM.

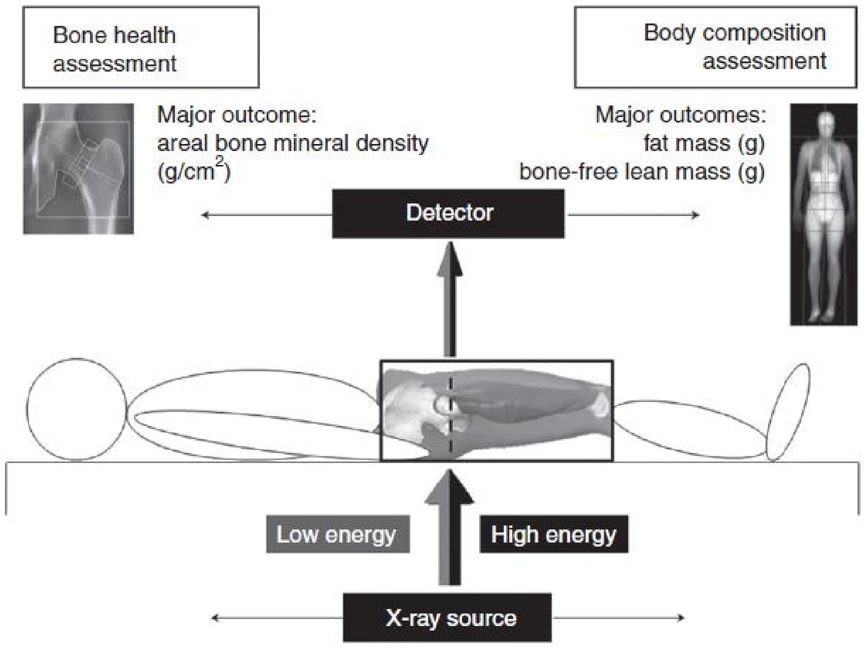

Figure 3. DXA measures X-rays passing through the body at high and low energies. The X-ray source is located below the subject, and the attenuation is measured by the detector hovering over the table (Toombs, 2012).

For the purpose of this study, DXA is appropriate to compare with $\%BF_{VTGpred}$ and $\%BF_{VTGmeas}$. ADP is a two compartment model of estimating body composition dividing body composition into FM and FFM based on measurements of density (Siri, 1961). Volume plays an important role in determining density. The assumptions made by the Bod Pod software to account for lung volumes does not represent outliers well, especially if an outlying variable can change the Bod Pod's software calculation for body volume (effect of SAA or VTG). As a result, the assumptions used by VTG_{pred} have to be carefully considered before choosing whether it is appropriate. Measures can potentially be inaccurate for individuals who deviate from the constants that the devices are fundamentally based on (Kohrt, 1995; D. Wagner, 2015). This can potentially also be true in terms of accuracy of estimating lung volumes in an obese population, who tend to breathe at lower than normal operational lung volumes (Salome, 2010).

A benefit of DXA in comparison to ADP is that estimates of body composition are independent from measures of lung volumes (Smith-Ryan, 2017), and it does not use density to predict body fat. Although the trueness of the measurement of body composition using DXA has promise in the future, it still is debated whether or not it can be considered a reference standard (Kohrt, 1995; Laskey, 1996; Pietrobelli, 1996; Shiel, 2018). Despite these disagreements, DXA is a commonly used tool in research that yields accurate and precise measurements of soft tissue (Svendsen, 1993). The body composition of pigs were measured using DXA, then with chemical analysis after postmortem homogenization, the respective r value for the comparison was > 0.97 with a SEE < 3% (Svendsen, 1993). ADP has often been compared to DXA and showed high correlations within several populations (Ballard, 2004; Levenhagen, 1999; Nunez, 1999; Radley, 2005). ADP is an attractive method to estimate body composition due to its ease of use, and its ability to accommodate larger body volumes; it is important to see how these two common tools of measuring body composition compare with one another.

The state of obesity is a well-known complication for estimates of body composition with both ADP and DXA. Densitometry via ADP assumes a constant FFM hydration and density (Brozek, 1963; Siri, 1961). In an obese population these assumptions can be inaccurate due to unequal distribution of fluids and adiposity throughout the body (Brozek, 1963; Siri, 1956, 1961; Waki, 1991). The ratio of attenuation between a high energy photon beam and low intensity photon beam can be used to identify components within the body. Hydration status can skew the resulting *r* values of soft tissue, which can change the result of the subsequent FM. For example, an addition of 1 kg of extra cellular fluid to the reference man could result in a 0.6% underestimation of body fat (Pietrobelli, 1996). Ideally, the more compartments that are not assumed, the more accurate the resulting measurements will be (Smith-Ryan, 2017). However more detailed methods to account for subdivisions of body composition such as total body water (TBW) are more expensive, and less broadly used in clinical and research settings (Das, 2003, 2005). Therefore, it is important to compare common tools of body composition assessment such as ADP and DXA in a variety of situations involving obese individuals to further validate this equipment in accurately estimating body composition.

Methods

Subjects

Subjects were recruited via email, posted flyers, and word of mouth within the community. To be included in the study, subjects had to be between the ages of 18 and 45 yr. Subjects were apparently healthy (i.e., no signs or symptoms of disease) and were non-smokers. Subjects with a BMI of 18.5-24.9 $kg{\cdot}m^{-2}$ were classified as NW. Subjects with a BMI of 30.0-39.9 $kg{\cdot}m^{-2}$ were classified as OB.

Subjects were excluded from the study if their BMI was not within the mentioned ranges. Subjects were also excluded for taking medication that effected hydration level (diuretics and/or corticosteroids), if they had a history of smoking, had any lung dysfunction that could potentially change lung volumes, or if subjects had any type of metal plating within their body. The project was approved by the local Institutional Review Board (IRB# 18-0355), and all subjects voluntarily provided informed consent prior to participation.

Study Design and Protocol

All testing procedures were completed within a single laboratory visit. Prior to the study visit, subjects were emailed and asked to bring form fitting clothing. Upon arrival, subjects completed an informed consent, medical health history questionnaire, and a 24-hour health history questionnaire. Subsequently, body composition was estimated using ADP with VTG_{pred}, and VTG_{meas}, and with the DXA protocol. Test by DXA or methods using ADP were selected in random order. When ADP was chosen, VTG_{pred}, and VTG_{meas} were selected in random order.

Body Composition with ADP using VTG_{pred}

Steps to calibrate and measure the Bod Pod were consistent with recommendations by the Bod Pod user's manual. After the Bod Pod was powered on, the quality control calibration was used to calibrate the pressure transducers within the chamber. The chamber was calibrated using a capsule with a known volume (50.122 L). The Bod Pod weight scale also was calibrated using a standard 20 kg weight. The general population equation was used to predict VTG in all subjects. Before each subject entered the chamber, they were asked to remove all jewelry and other SAA other than skin tight gear. A swim cap was placed on each subject's head to exclude isothermal air compression of trapped gas within the hair. Body mass was recorded using the Bod Pod's scale. The body volume test was initiated once each subject remained motionless within the Bod Pod during the time of each body volume measurement. For one successful trial, body volume was measured at least two times. If the two body volumes were more than 5% different, a third body volume measurement was initiated. The average value from the two body volumes that were less than 5% different, was adjusted by a proprietary correction factor and then subsequently used as the volume component in the calculation of density. If all three body volumes were greater than 5% different from each other, the entire trial was repeated. Three successful trials were completed by each subject. Measurements reported from this portion of the visit included VTG_{pred}, $\%BF_{VTGpred}$, FM from ADP using VTG_{pred} ($FM_{VTGpred}$) and FFM from ADP using VTG_{pred} ($FFM_{VTGpred}$).

Body composition with ADP using VTG_{meas}

Calibrations for the Bod Pod using VTG_{meas} were similar to calibrations for VTG_{pred}, except before calibration of the pressure transducers, a disposable tube and antimicrobial filter were added to a port inside the chamber, along with a nose clip that was clipped to the filter. These pieces of equipment were used during the panting maneuvers; calibrating the pressure transducers with the equipment inside the chamber corrected for the added volume said equipment introduces during body volume measurement. Before the subject entered the Bod Pod, they were thoroughly instructed through the techniques of the test to measure VTG. Each subject was asked again to remove all jewelry or SAA other than form fitting clothing. Body mass was recorded using the Bod Pod's scale. The body volume measurement was identical to the VTG_{pred} method, except the disposable tube, antimicrobial filter, and nose clip were in the chamber during each measurement. When the body volume measurements met the same criteria as for ADP with VTG_{pred}, the VTG_{meas} was initiated. Each subject was asked to place their hands on their cheeks and breathe through the internal chamber tube at a rate guided by the computer monitor while wearing a nose clip. After V_t was established, the Bod Pod instructed the subject to perform a soft panting maneuver. At the end of an exhalation, an occlusion occurred during an inspiration of a pant. With the mouth occluded the pressure measured at the mouth during an inspiratory maneuver is equal to the pressure within the lungs and can be used to calculate lung volume using Boyle's law (Dubois 1965). Following the occluded inspiratory effort, the airway was reopened and the subject came off of the mouthpiece. The VTG_{meas} was considered acceptable if the maneuver received a merit score below 10 and airway pressure below 30 cmH_2O (the calculation for merit score was proprietary) as indicated by the Bod Pod software. If a maneuver was deemed unacceptable, the manufacturer recommended the technician ensure the subject pant gentler and make a tight seal around the mouthpiece. The VTG was measured after each body volume measurement. The three body composition trials with three reproducible measures of VTG (error of 5%) were reported. Measurements reported from this portion of the visit included VTG_{meas}, $\%BF_{VTGmeas}$, FM from ADP using VTG_{meas} ($FM_{VTGmeas}$) and FFM from ADP using VTG_{meas} ($FFM_{VTGmeas}$).

Body Composition using DXA

A standard whole body scan protocol was used to measure body composition via DXA. To calibrate the DXA machine, a phantom spine with a known (i.e., standard) density was positioned between two laser cross hairs and the attenuation of X-ray light through the phantom spine was measured. The calibration passed if measures of density were similar to the actual density of the reference phantom.

Before testing could commence, the subject's information, including age, height, and weight were entered into the system software. Subjects were asked to lay in the supine position on the scanning table. An attempt to straighten/align the hips prior to the scan was made by the researcher by instructing subjects to relax their waist while the researcher gently pulled at the subject's ankles. Subjects were then asked to sit straight up, take a big breath in, hold their chin to their chest, and lay back down. This was to ensure that subjects' spines were positioned properly for body composition analysis. After the subject was properly positioned, they were told to point their toes toward each other, then a harness fastened them in that fixed position. This was done so the full dimensions of the feet could be scanned.

Then the two minute scan was initiated. Measurements reported from this portion of the visit included $\%BF_{DXA}$, percent of trunk fat from DXA, FM from DXA, and FFM from DXA.

Data Analyses

Independent t-test were used to test for group differences in age, weight, and height. A 2 x 2 mixed-design analysis of variance was used to examine the effects of group and method on measurements of VTG. A 2 x 3 mixed-design analysis of variance was used to examine the effects of group and method on measurements of %BF. Sphericity was tested using Mauchly's test. When the assumption of sphericity was violated, a Geisser-Greenhouse correction factor was applied. Eta-squared (η^2) was used to quantify the effect size of the variance between measures. Pearson correlation coefficients (*r*) were used to assess the relationship between measured variables. Significance was set at $\alpha = 0.05$. Data were reported as mean ± standard deviation (SD).

Results

4.1 Subject Characteristics

A total of 38 subjects volunteered to participate in the study. Subjects did not qualify due to having a BMI outside of the qualifying range. Twenty-four (N=24) subjects qualified for the study and completed all study procedures. All subjects were non-smokers, were apparently healthy, and were deemed fit to participate in the study based on a brief medical history, and 24-hour health history questionnaire. Of the 24 subjects who participated in the study 15 were classified as normal weight (four males) and nine were classified as obese (nine males). Anthropometric data are provided in Table 1.

Table 1.

Subject Characteristics

	Age (yr)	Wt (kg)	Ht (cm)	BMI ($kg \cdot m^{-2}$)
NW (n=15)	25 ± 7	62.4 ± 6.9	167.4 ± 5.0	22.2 ± 1.7
NW Range	18 - 41	52.2 - 71.8	161.8 - 175.0	18.6 - 24.9
OB (n=9)	24 ± 7	103.5 ± 12.7*	179.4 ± 10.7*	32.1 ± 1.9*
OB Range	21 - 27	91.3 – 128.7	161.1 – 197.5	30.3 - 35.9

Values are mean ± SD. NW, normal weight; OB, obese; Wt, weight; Ht, height; BMI, body mass index. * Significantly different compared with NW ($p < 0.01$).

Measured vs Predicted Thoracic Gas Volumes

Table 2

Predicted and measured VTG

	VTG_{pred}(L)	VTG_{meas}(L)	Mean Δ(L)
NW (n=15)	3.326 ± 0.232	3.353 ± 0.755	-0.027 ± 0.629
OB (n=9)	4.000 ± 0.515	3.577 ± 0.916	0.420 ± 0.578

Values are mean ± SD. NW, normal weight; OB, obese; VTG_{pred}, predicted thoracic gas volume; VTG_{meas}, measured thoracic gas volume; Mean Δ, mean difference of VTG_{pred} and VTG_{meas}.

Mean values for VTG_{pred} and VTG_{meas}, along with the mean differences between the two measurements, are provided in Table 2. There was no group by method interaction ($F_{1,22} = 3.017$, $p = 0.096$, $\eta^2 = 0.11$). Additionally, there was no main effect of method ($F_{1,22} = 2.330$, $p = 0.141$, $\eta^2 = 0.09$) or main effect for group ($F_{1,22} = 3.685$, $p = 0.068$, $\eta^2 = 0.14$). The differences between VTG_{pred} and VTG_{meas} were not significantly related with BMI ($r = 0.33$, $p = 0.11$). However, the differences between VTG_{pred} and VTG_{meas} were significantly related with trunk fat percentage ($r = 0.47$, $p = 0.02$).

Figure 4 depicts the individual differences between VTG_{pred} and VTG_{meas} (i.e., residuals) plotted against the corresponding VTG_{pred} for all subjects. In the NW group there were approximately equal numbers of positive and negative residuals. However, in the OB group there tended to be more positive than negative residuals. The differences between VTG_{pred} and VTG_{meas} were not significantly related to VTG_{pred} ($r = -0.02$, $p = 0.945$).

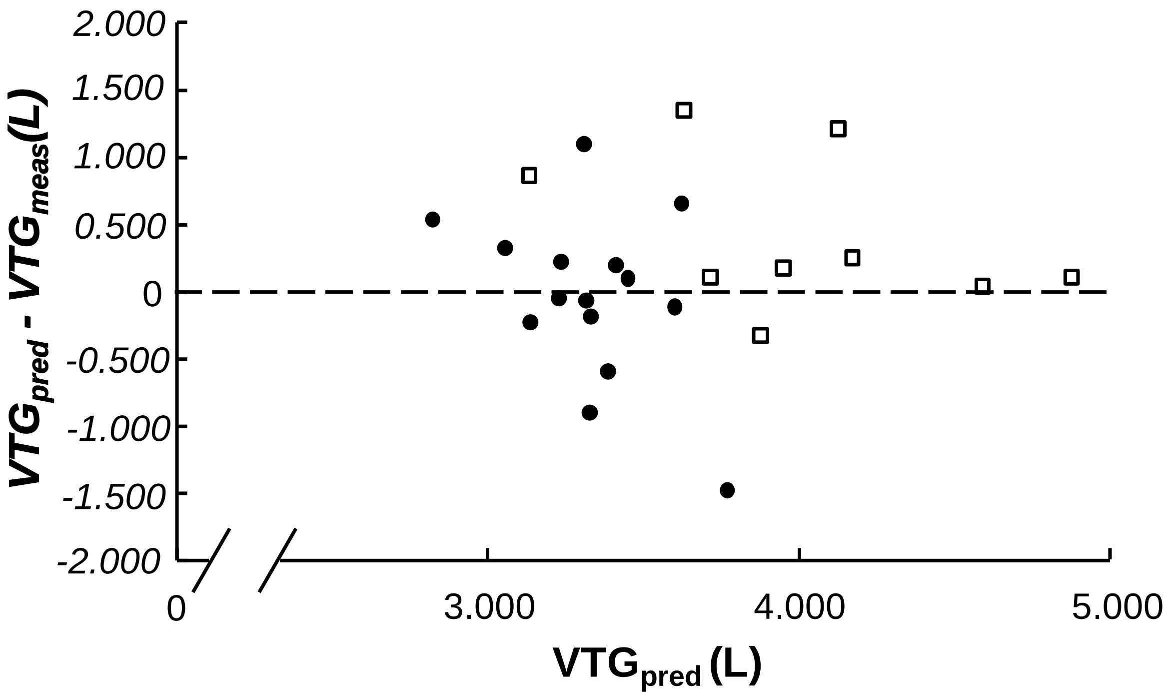

Figure 4. Thoracic gas volume difference (VTG_{pred} - VTG_{meas}) against the mean of VTG_{pred} in normal weight (•) and obese (□) subjects; VTG_{pred}, predicted thoracic gas volume; VTG residuals; difference between VTG_{pred}, and VTG_{meas} ($r = -0.02$, $p = 0.945$).

Measures of Body Fat using ADP and DXA

Table 3

Measures of Body Fat using ADP and DXA

	$\%BF_{VTGpred}$(%)	$\%BF_{VTGmeas}$(%)	$\%BF_{DXA}$(%)
NW (n=15)	24.7 ± 6.4	24.5 ± 5.3	26.1 ± 5.1
OB (n=9)	32.9 ± 4.3	32.2 ± 3.9	30.9 ± 3.0

Values are mean ± SD. NW, normal weight; OB, obese; $\%BF_{VTGpred}$, percent body fat from predicted thoracic gas volume; $\%BF_{VTGmeas}$, percent body fat from measured thoracic gas volume; $\%BF_{DXA}$, percent body fat from DXA.

Table 4

Measures of FM using ADP and DXA

	$FM_{VTGpred}$(kg)	$FM_{VTGmeas}$(kg)	FM_{DXA}(kg)
NW (n=15)	15.5 ± 4.8	15.4 ± 4.2	16.6 ± 4.3
OB (n=9)	34.0 ± 5.1	33.2 ± 5.2	32.6 ± 5.3

Values are mean ± SD. NW, normal weight; OB, obese; Values are mean ± SD; $FM_{VTGpred}$, fat mass from predicted thoracic gas volume; $FM_{VTGmeas}$, fat mass from measured thoracic gas volume.

Table 5

Measures of FFM using ADP and DXA

	$FFM_{VTGpred}$(kg)	$FFM_{VTGmeas}$(kg)	FFM_{DXA}(kg)
NW (n=15)	46.9 ± 6.1	47.0 ± 5.5	46.7 ± 5.2
OB (n=9)	69.6 ± 10.4	70.3 ± 9.9	56.5 ± 14.6

Values are mean ± SD. NW, normal weight; OB, obese; Values are mean ± SD; $FFM_{VTGpred}$, fat free mass from predicted thoracic gas volume; $FFM_{VTGmeas}$, fat free mass from measured thoracic gas volume.

Mean values for $\%BF_{VTGpred}$, $\%BF_{VTGmeas}$, and $\%BF_{DXA}$ can be found in Table 3. There was a significant group by method interaction for the measure of %BF ($F_{2,44}$ = 10.060, p = 0.001, η^2 = 0.31). Additionally, there was a significant main effect for group in %BF ($F_{1,22}$ = 10.944, p = 0.003, η^2 = 0.01), but not for method ($F_{2,44}$ = 0.663, p = 0.479, η^2 = 0.33). Mean values for $FM_{VTGpred}$, $FM_{VTGmeas}$, and FM_{DXA} can be found in Table 4. There was a significant group by method interaction for the measures of FM ($F_{2,44}$ = 9.944, p < 0.001, η^2 = 0.30). Additionally, there was a significant main effect for group in FM ($F_{1,22}$ = 78.616, p < 0.001, η^2 = 0.11). Mean values for $FFM_{VTGpred}$, $FFM_{VTGmeas}$, and FFM_{DXA} can be found in Table 5. There were a significant group by method interaction for the measures of FFM

($F_{2,44}$ = 20.995, $p < 0.001$, $\eta^2 = 0.36$). Additionally, there were significant main effects for group ($F_{1,22}$ = 58.936, $p < 0.001$, $\eta^2 = 0.04$) and method in FFM measures ($F_{2,44}$ = 0.998, $p < 0.001$, $\eta^2 = 0.27$). The mean differences of $\%BF_{VTGpred}$, and $\%BF_{VTGmeas}$ plotted against the measure of $\%BF_{VTGpred}$ in the NW and OB groups are shown in Figure 5. At lower $\%BF_{VTGpred}$, there were large negative residuals, but the residuals were positive at higher $\%BF_{VTGpred}$. As a result, the differences between $\%BF_{VTGpred}$ and $\%BF_{VTGmeas}$ were significantly related to $\%BF_{VTGpred}$ ($r = 0.60$, $p = 0.002$). In the OB group, the majority of the residuals were positive.

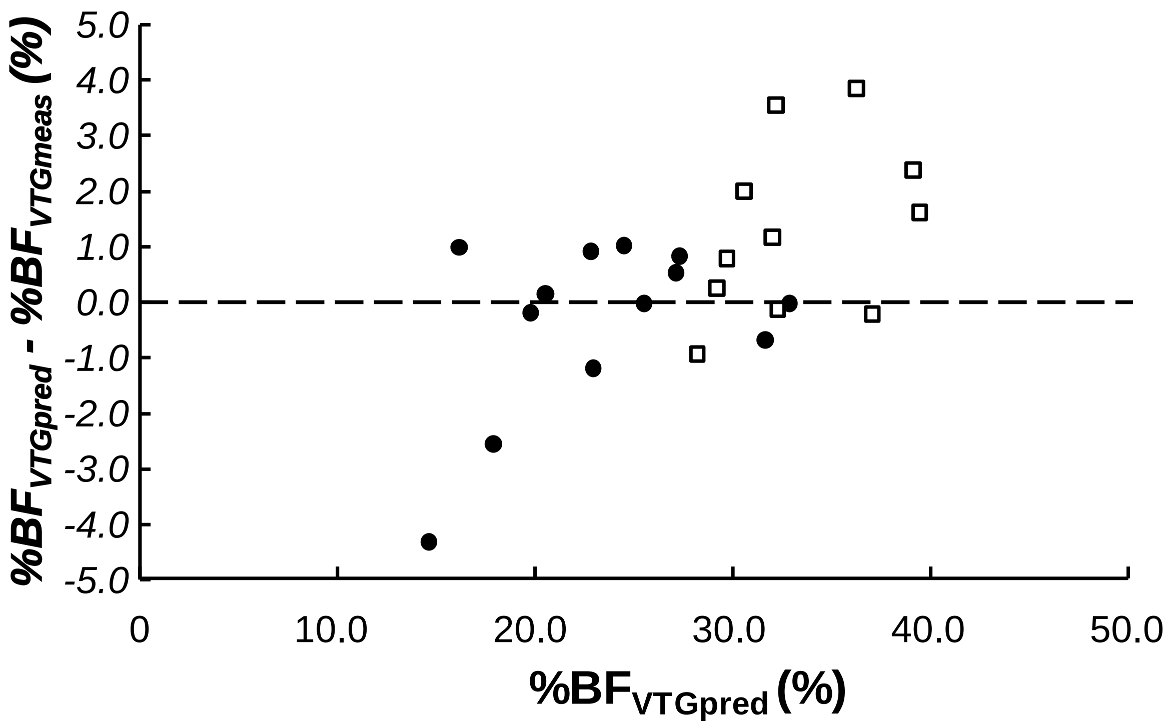

Figure 5. Percent body fat difference ($\%BF_{VTGpred}$ - $\%BF_{VTGmeas}$) across $\%BF_{VTGpred}$ in normal weight (•) and obese (□) subjects; $\%BF_{VTGpred}$, percent body fat from predicted thoracic gas. volume; $\%BF_{VTGmeas}$, percent body fat from measured thoracic gas volume; %BF Residuals, the difference of $\%BF_{VTGpred}$, and $\%BF_{VTGmeas}$ ($r = 0.60$, $p = 0.002$).

The amount of error of estimating $\%BF_{VTGpred}$ is shown in Figure 6. The differences between VTG_{pred} and VTG_{meas} were significantly related with the differences between $\%BF_{VTGpred}$ and $\%BF_{VTGmeas}$ ($r = 0.92$, $p < 0.001$). In the NW group, there was an even distribution of individuals who had their VTG either under or over predicted compared with VTG_{meas}. A large cluster of NW subjects had no large differences both in the estimation of VTG and estimation of %BF compared with respective measured parameters. The majority of the obese subjects had both their VTG and %BF overestimated.

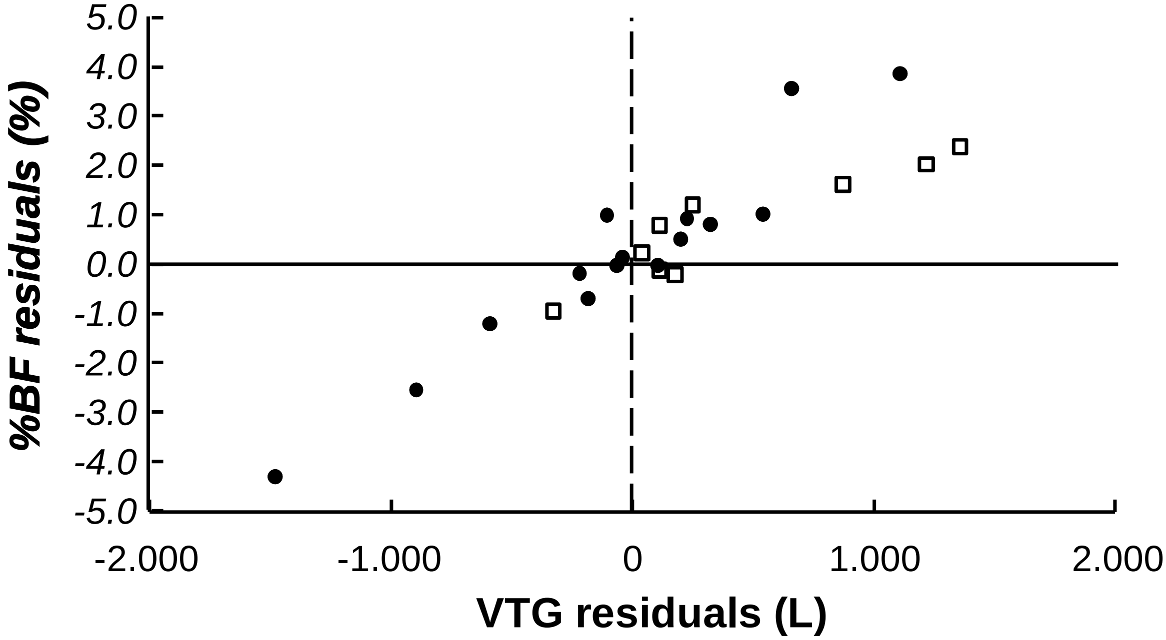

Figure 6. Difference in %BF ($\%BF_{VTGpred}$ - $\%BF_{VTGmeas}$) as a function of difference in VTG (VTG_{pred} - VTG_{meas}) for normal weight (•) and obese (□) subjects; VTG residuals; difference between VTG_{pred}, and VTG_{meas}; %BF Residuals, the difference of $\%BF_{VTGpred}$, and $\%BF_{VTGmeas}$ ($r = 0.92$, $p < 0.001$).

The mean differences of measured $\%BF_{DXA}$ and $\%BF_{VTGpred}$ are plotted against $\%BF_{DXA}$ in NW and OB subjects in Figure 7. The differences between $\%BF_{VTGpred}$ and

%BF_{DXA} were significantly related to %BF_{DXA} ($r = 0.92$, $p < 0.001$). In the NW group, there were more positive residuals; in the OB group, there were more negative residuals. Figure 8 depicts the mean differences of measured %BF_{DXA} and %$BF_{VTGpred}$ plotted against %BF_{DXA} in NW, and OB groups. In the NW group there were more positive residuals; in the OB group, there were more negative residuals. The differences between %$BF_{VTGmeas}$ and %BF_{DXA} were significantly related to %BF_{DXA} ($r = 0.95$, $p < 0.001$).

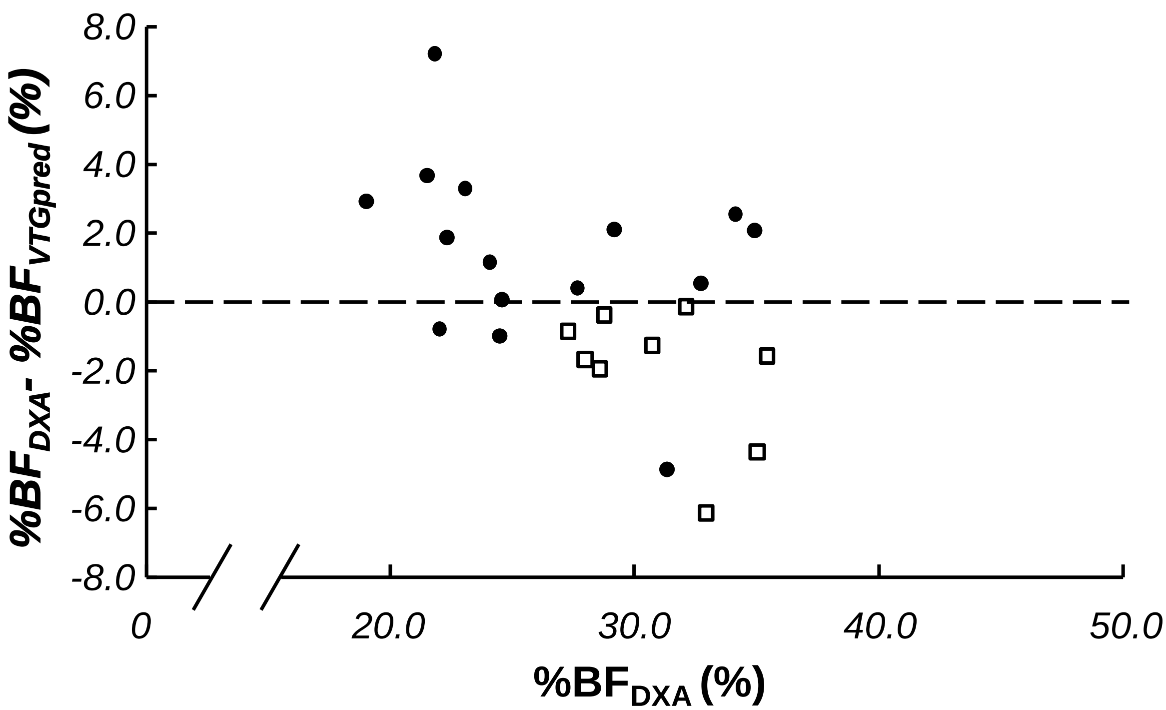

Figure 7. Percent body fat difference (%BF_{DXA} - %$BF_{VTGpred}$) against the mean of %BF_{DXA} in normal weight (•) and obese (□) subjects; %$BF_{VTGpred}$, percent body fat from predicted thoracic gas volume; %BF_{DXA}, percent body fat from the DXA ($r = 0.92$, $p < 0.001$).

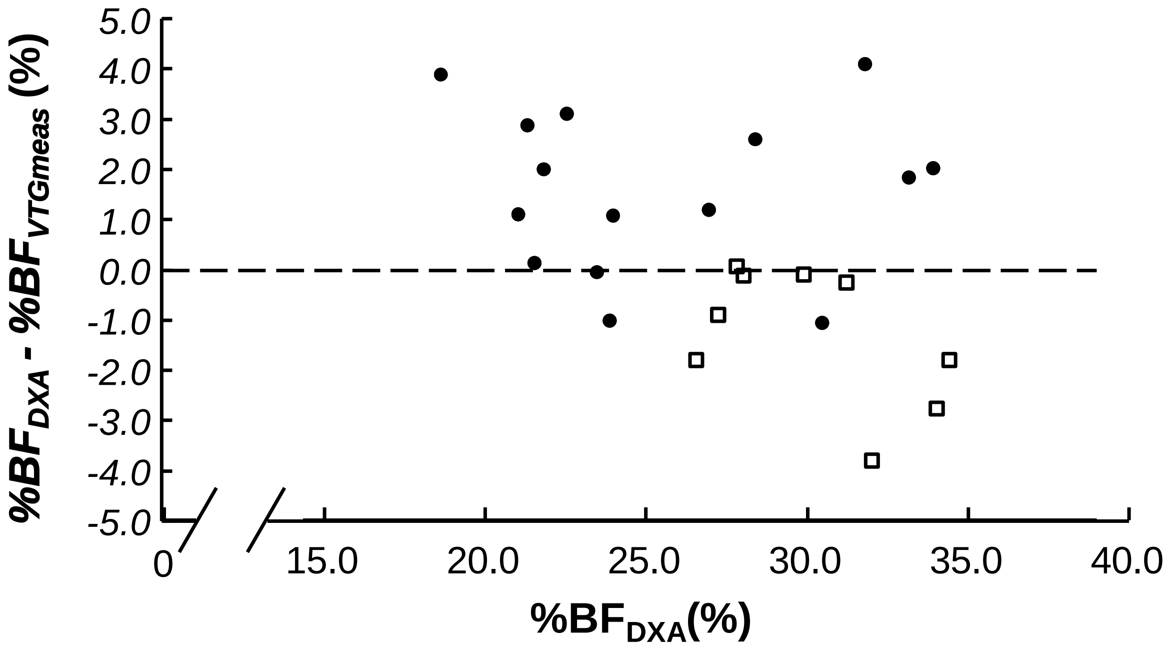

Figure 8. Percent body fat difference (%BF_{DXA} - %$BF_{VTGmeas}$) against the mean of %BF DXA in normal weight (•) and obese (□) subjects; %$BF_{VTGmeas}$, percent body fat from measured thoracic gas volume; %BF_{DXA}, percent body fat from the DXA (r = 0.95, p < 0.001).

Discussion

Main Findings

The differences between VTG_{pred} and VTG_{meas} were not significantly different within the OB and NW subjects, but the moderate effect size (η^2) indicates differences may be observed with a larger sample size. Differences between VTG_{pred} and VTG_{meas} were not associated with BMI but were significantly related to trunk fat percentage. OB played a significant role into the error of %BF estimations. Within the OB group, %BF was reduced using DXA than with either ADP method. In contrast, %BF was greater using DXA than with either ADP method in the NW group. The differences between VTG_{pred} and VTG_{meas} were strongly related to differences between $\%BF_{VTGpred}$ and $\%BF_{VTGmeas}$. Consequently, because the OB group showed a trend of having their VTG overestimated (compared to when measured), OB individuals also had overestimated values of %BF. Although this study is underpowered, there appears to be an impact of body composition on estimates of %BF due to altered operational lung volumes; this calls for more attention to be focused on the method of measurement used in an obese population.

Subject Characteristics

All of the NW and OB subjects were apparently healthy, non-smokers. Each group displayed body composition (%BF) typical of their BMI classification. The two groups differed greatly by sex, with 11 females in the NW group and no females in the OB group. Males tend to have more fat free mass, and females tend to have more fat mass (Wellens, 1994). While BMI is not directly related to %BF, the %BF of the NW group using either ADP or DXA was consistent with %BF that are typically observed in relation to BMI with both males and females in a NW population; males and females with a BMI of less than 25 $kg \cdot m^{-2}$ usually have a %BF that was below 25% and 35% respectively (Hanes, 2014; Lorenzo, 2003). This evidence is consistent with what this study found, with methods using ADP or DXA mean %BF ranged from 24% – 27%. Despite the OB group being entirely males, their higher BMI was not due to just a significant height difference, but also a larger %BF, males who were classified as obese had %BF greater than 30% using ADP or DXA. This finding is consistent with a typical %BF in this population (%BF 30% or greater) (Lorenzo, 2003). Regardless of sex differences, decreased respiratory compliance and operational lung volumes are typical in obese adults (Harris, 2005; Norman, 1960). Thus, while the current study only observed obese males, obese females would be expected to have differences in VTG at rest due to decreases in FRC that are associated with a larger BMI similar to males.

VTG Differences

Being obese did not significantly over predict VTG compared to normal weight adults. There was also no relationship between BMI and difference between VTG_{pred} and VTG_{meas}; however, there was a significant positive relationship between trunk fat percentage and differences between VTG_{pred} and VTG_{meas}. BMI is known to be associated with decreases in operational lung volumes, primarily because of the increased adiposity around the chest wall and abdominal cavity (Koenig, 2001b; Littleton, 2012; Sampson, 1983). Although there were no significant differences observed between VTG_{pred} and VTG_{meas} in the OB adults, the current effect size may indicate that a larger sample size would result in significant differences observed between the methods in the OB but not the NW subjects. Yet, the lack of statistical significance could either be because the measured VTG was not related to resting FRC, or the excess fat of the OB group was not distributed in an area that could impede total respiratory compliance. The relationship that we found with trunk fat percentage and VTG differences indicate that the small differences that we did see were in part, due to the location of fat. Based on the relationships described above regarding %BF and VTG, greater differences in VTG due to trunk fat percentage could result in further error on %BF estimations by ADP.

VTG is not FRC

The Bod Pod predicts lung volumes based on the estimation of the midpoint of tidal volume, plus the predicted FRC (Aitkens, 1995). Although VTG and FRC are closely related, they are not the same. VTG refers to the amount of volume in the lungs at the time of measurement. During a measurement, a subject may exhale to FRC, but at the moment they inhale, lung volumes will no longer be at FRC. To take into consideration the net amount air in the lungs at any given point in the test, the midpoint best represents the average amount of air that is in the lungs. As such, predicted VTG is expected to be slightly larger than FRC.

Minor alterations in breathing patterns or positioning may alter the volume amount within the lungs at the time of measurement. In terms of the actual measurement of lung volumes, it is difficult to get true measures of tidal volume (V_t) using standard techniques. Typical methods to measure lung volumes usually involve a pneumatic device connected to the subject, along with a firmly fastened nose clip. These methods are often uncomfortable and could result in alterations to normal, resting breathing patterns. A study was done observing the differences in breathing patterns with the use of pneumatic device and nose clip, versus the less invasive magnetometer in subjects while resting in bed (Figure 9). In nearly all cases the addition of the respiratory apparatus caused a subsequent increase in V_t, (124 ± 80 ml) and a decrease in breathing frequency (Gilbert, 1972). In other words, when a nose clip and spirometric measuring device were added, the very values that were intended on being measured were altered. Therefore it is important to note that due to measurement of VTG within the Bod Pod, lung volumes may have been altered.

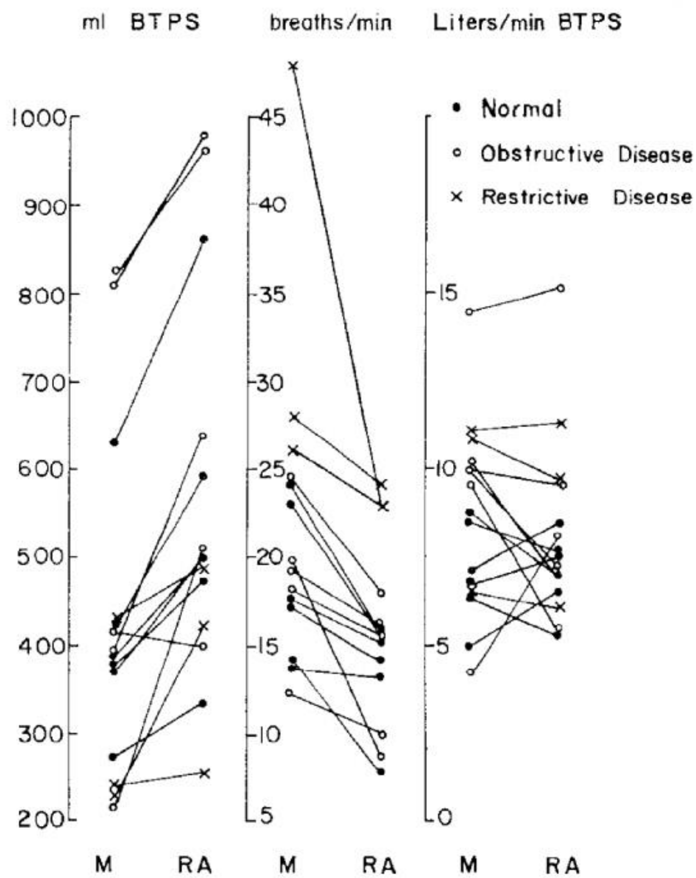

Figure 9. Changes while lying supine at rest to tidal volumes from magnetometer to respiratory apparatus; breathing frequency, and ventilation. M. magnetomoter; RA. respiratory apparatus (Gilbert, 1972).

The under-prediction of NW VTG may be, in part, due to these altered breathing patterns to compensate for changes not usually experienced during uninterrupted breathing.

Subjects may breathe at higher lung volumes compared with what is predicted according to age and height because they are breathing atypically.

Mean differences in lung volumes observed in the OB group, in contrast to the normal weight group, averaged 816 ml less than what was predicted. Due to the increased adiposity around the thoracic cavity usually associated with those with higher BMI, lung volumes in this population are decreased (Jones, 2006), particularly in those with a BMI ≥ 30 kg·m^2 (Figure 10).

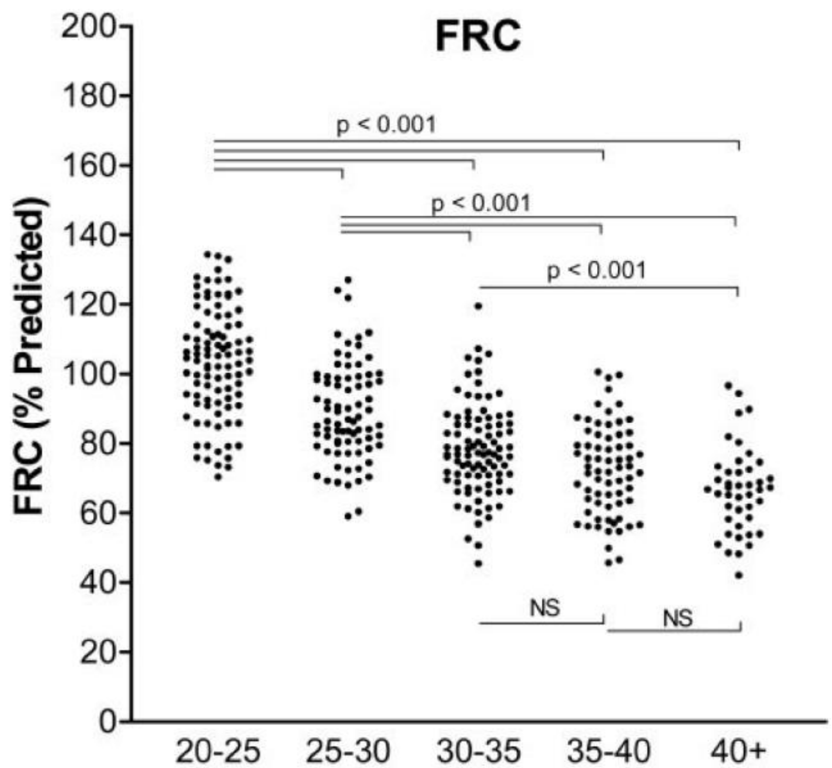

Figure 10. Effects of BMI on functional residual capacity (FRC); NS, not significant (Jones, 2006).

Although VTG and FRC are different measures, if FRC decreases, VTG will also decrease. Measured VTG in the obese group was approximately 75% of predicted, while in the two groups combined, VTG was measured to be 86 ± 18% of predicted. This finding is consistent with other studies examining decreases in lung volumes attributed to obesity. While significant differences between groups were not found, the OB group had lung volumes over-predicted by the Bod Pod, as a result, had an over-estimated %BF. While this study is under-powered, these trends have the potential to be significant with a larger sample of obese adults. If in fact these trends remain true, this would indicate that those with higher BMI will have their VTG, and perhaps the resulting %BF, over-estimated when not measuring VTG.

%BF Estimates

There were no significant differences in measures of %BF by ADP. However, BMI and/or body composition did affect $\%BF_{DXA}$ differently than in normal weight adults. Specifically, $\%BF_{DXA}$ in OB adults was lower than ADP by approximately 2%. In contrast, $\%BF_{DXA}$ in NW adults was greater than ADP by approximately 2%. A strong correlation between VTG differences ($VTG_{pred} - VTG_{meas}$) and %BF differences ($\%BF_{VTGpred} - \%BF_{VTGmeas}$) indicated that errors in VTG will result in errors in %BF. Low $\%BF_{VTGpred}$ in the NW group resulted in larger differences in $\%BF_{VTGpred}$ and $\%BF_{VTGmeas}$. Upon further analysis 8 normal weight individuals displayed measured lung volumes that averaged to be 113 % of the predicted VTG. These under estimated predictions of VTG could have resulted in underestimation of %BF in the NW group. For large amounts of $\%BF_{VTGpred}$, typical in obesity differences were also greater.

Being OB had a significant effect on the values of estimated %BF across the three methods (VTG_{pred}, VTG_{meas}, and DXA). A significant main effect by group indicates that OB adults, in fact, had more %BF then their NW counterparts. Ultimately, being OB was not only related with greater %BF but larger differences between methods for estimating %BF.

When the differences of VTG_{pred} and VTG_{meas} were compared to the differences of $\%BF_{VTGpred}$, and $\%BF_{VTGpred}$, there was a strong positive correlation (r = 0.92, $p < 0.001$), showing that the error in predicting VTG will affect the subsequent estimate of %BF from ADP. A large cluster of NW subjects did not have large differences in VTG_{pred} and VTG_{meas}, and therefore, the %BF estimates often agreed between the two methods. The large majority of OB subjects displayed an over estimated VTG, which resulted in an overestimation of %BF.

When $\%BF_{DXA}$ was compared to VTG_{pred} and VTG_{meas} (Figure 7, Figure 8), the DXA estimation of %BF was lower in the OB group, but tended to estimate higher %BF than VTG_{pred} and VTG_{meas} in the NW group. DXA has been shown to result in lower %BF estimates compared to ADP estimates of %BF in obese individuals (Sampson, 1983). For example, in 57 severely obese women, DXA estimated %BF to be 2.4% lower than ADP (Bedogni, 2013). In contrast, in normal weight adults, measures of $\%BF_{DXA}$ have been found to be larger than ADP by 3% (Levenhagen, 1999). In females the difference in estimates from DXA and ADP appeared to be more substantial than in males. The results of our study are consistent with other previous findings, however there were some discrepancies. For example, a study including 109 participants, who divided groups by BMI, reported %BF from DXA in their NW and OB group to be approximately 2.5% higher than $\%BF_{VTGpred}$. Yet, the severely OB group values for $\%BF_{DXA}$ was 2.7% less than $\%BF_{VTGpred}$ (Hanes, 2014). A study with 15 normal weight subjects, and 19 overweight/obese subjects reported $\%BF_{VTGpred}$ to be 2.43% greater than $\%BF_{DXA}$ and 1.46% less than $\%BF_{DXA}$ in the overweight/obese group. Some of the differences observed in OB adults may have been mitigated by grouping together overweight and obese adults.

Error in %BF Estimates

Measuring true body composition is not yet possible in living humans. When the ADP and DXA devices estimate %BF, there are assumptions that are made of the composition of the body. For example, with ADP and DXA, a constant fat free mass hydration status is assumed (Aitkens, 1995; Pietrobelli, 1996; Siri, 1961). Hydration status that may deviate from what is normal has the potential to increase the error in %BF estimates.

DXA uses a three-compartment model to estimate body composition. Theoretically, by taking more compartments of the body into consideration, resultant measures of body fat should be more accurate. An added benefit of DXA, in contrast to ADP, is that the calculation of %BF is independent from the amount of gas in the lungs at any given time of measurement. Although it is impossible to get a direct measure of %BF in a living human, results from DXA should provide a closer estimation to the true body composition than the two-compartment model used in ADP.

Errors in calculated %BF by DXA arise from factors that will affect the attenuation of the different energy level X-ray beams that pass through the body. Some of these factors include tissue thickness, hydration status, and body fat distribution all of which are altered with obesity (Hanes, 2014; Jensen, 2019). Past studies have shown strong agreement in NW populations and measures of %BF from DXA and ADP (Ballard, 2004; Flakoll, 2004). Observed differences in %BF in DXA compared with ADP could be due to the quantity and location of fat distribution in the NW versus OB population. Body composition can be greatly affected by confounding factors present in children and youth (≤18 years) along with older adults (≥ 40 years). Within these age groups, there are several body composition changes that could skew resultant values of FM and FFM independent of FRC, methodology used in determining %BF in OB individuals compared to their NW counterparts. In FFM of children and youth, there are changes in water and mineral content that tend to violate the soft tissue density assumptions for this population (Boileau, 1985; Lohman, 1984; Siri, 1961). With older groups, there are changes in bone mineralization and hydration of the fat free mass due to aging and factors such as menopause and disease states. Methods based on the two-compartment model to estimate FM and FFM may also be limited by these deleterious changes (Baumgartner, 1991; Clasey, 1999; Fields, 2004; Heymsfield, 1989; Toth, 2000). Similarly in obese populations, hydration status and total body water (TBW) deviate from what is appraised as normal, and should be considered when analyzing body composition in obese adults.

Future studies examining body composition in normal weight and obese individuals should consider a more detailed classification of fatness that considers the distribution of fat throughout the body. For example, values of waist and hip circumference could prove helpful in showing supporting evidence of %BF changes concurrent with different methods of body composition measurement. Further, because hydration status of fat and muscle cells can play a key role in changing the assumptions that uniform density suggest, measuring hydration status of the body will help refine estimations of body composition.

Conclusion

The differences observed in %BF estimates between VTG_{pred}, VTG_{meas}, and DXA in this study indicate that methods of measuring body composition via ADP cannot be used interchangeably with DXA. Additionally, individuals monitoring body composition should be consistent with the method and device that they are utilizing. With weight loss, differences between VTG_{pred} and VTG_{meas} will be mitigated, and subsequent estimates of %BF with ADP will be more similar. With changes in weight, DXA, in contrast to ADP, will give the most similar estimates of %BF compared with a four-compartment model method. It is important to consider the effect that obesity may have on body composition measurements using ADP, and to ensure that appropriate methods are being used to test this population.

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Appendix A

Raw Data

Screen Captures of Raw Data from Subject Information:

LN	STUDY	ID	GRP	STATUS	Ethnicity	AGE	DOB	SEX	CODE	HT (cm)	WT (kg)	WT:HT	BMI	HxDOE	snore-subjectiv	snore-objectiv	Hx Asth
1	**VTG**	**014**	**OB**	**Completed**	**Hisp**	**22**	**8/17/1996**	**M**	Mean	177.0	94.9	0.536	30.3	No	No	No	None
2	**VTG**	**015**	**OB**	**Completed**	**Not Hisp**	**21**	**.**	**M**	Mean	172.0	92.7	0.539	31.3	No	Yes	Yes	None
3	**VTG**	**016**	**NW**	**Completed**	**Not Hisp**	**34**	**2/19/1985**	**F**	Mean	169.5	53.5	0.316	18.6	No	No	No	None
6	**VTG**	**019**	**OB**	**Completed**	**Not Hisp**	**23**	**9/17/1995**	**M**	Mean	161.1	93.1	0.578	35.9	No	No	No	None
7	**VTG**	**020**	**NW**	**Completed**	**Not Hisp**	**23**	**4/5/1996**	**F**	Mean	171.2	66.3	0.387	22.6	No	No	No	None
8	**VTG**	**021**	**NW**	**Completed**	**Hisp**	**21**	**4/12/1998**	**M**	Mean	175.0	70.0	0.400	22.9	No	No	No	None
9	**VTG**	**022**	**NW**	**Completed**	**Not Hisp**	**32**	**12/5/1986**	**M**	Mean	163.5	59.0	0.361	22.1	No	No	No	None
10	**VTG**	**023**	**NW**	**Completed**	**Not Hisp**	**41**	**4/6/1978**	**F**	Mean	167.5	68.8	0.411	24.5	No	No	No	None
11	**VTG**	**024**	**OB**	**Completed**	**Not Hisp**	**23**	**8/27/1995**	**M**	Mean	173.4	91.9	0.530	30.6	No	Yes	Yes	None
12	**VTG**	**025**	**OB**	**Completed**	**Not Hisp**	**24**	**6/11/1995**	**M**	Mean	182.9	111.1	0.607	33.2	No	Yes	Yes	None
14	**VTG**	**027**	**NW**	**Completed**	**Not Hisp**	**20**	**12/7/1998**	**F**	Mean	172.5	71.8	0.416	24.1	No	Yes	Yes	None
15	**VTG**	**028**	**NW**	**Completed**	**Hisp**	**21**	**12/26/1997**	**F**	Mean	166.5	56.6	0.340	20.4	No	.	.	.
17	**VTG**	**030**	**OB**	**Completed**	**Not Hisp**	**25**	**3/25/1994**	**M**	Mean	191.5	115.0	0.600	31.4	No	No	No	None
18	**VTG**	**031**	**NW**	**Completed**	**Not Hisp**	**33**	**11/16/1985**	**F**	Mean	167.6	70.0	0.418	24.9	.	.	.	.
19	**VTG**	**032**	**NW**	**Completed**	**Not Hisp**	**18**	**12/17/2000**	**F**	Mean	166.5	64.7	0.389	23.3	No	No	No	None
20	**VTG**	**033**	**NW**	**Completed**	**Not Hisp**	**18**	**3/19/2001**	**F**	Mean	161.8	53.5	0.331	20.4	No	No	No	None
21	**VTG**	**034**	**NW**	**Completed**	**Not Hisp**	**19**	**4/17/2000**	**F**	Mean	164.0	55.0	0.335	20.4	No	No	No	None
22	**VTG**	**035**	**OB**	**Completed**	**Hisp**	**27**	**2/7/1991**	**M**	Mean	181.1	98.3	0.543	30.0	No	Yes	Yes	None
23	**VTG**	**036**	**NW**	**Completed**	**Not Hisp**	**22**	**3/3/1997**	**F**	Mean	155.0	52.2	0.337	21.7	No	No	No	None
24	**VTG**	**037**	**NW**	**Completed**	**Not Hisp**	**22**	**3/20/1996**	**M**	Mean	171.0	65.0	0.380	22.2	No	Yes	Yes	None
25	**VTG**	**038**	**NW**	**Completed**	**Not Hisp**	**23**	**4/14/1996**	**M**	Mean	171.5	68.1	0.397	23.2	No	No	No	None
26	**VTG**	**039**	**NW**	**Completed**	**Not Hisp**	**21**	**4/24/2019**	**F**	Mean	168.5	60.9	0.361	21.4	No	No	No	None
28	**VTG**	**041**	**OB**	**Completed**	**Not Hisp**	**22**	**3/17/1997**	**M**	Mean	178.5	106.1	0.594	33.3	No	No	No	None
29	**VTG**	**042**	**OB**	**Completed**	**Not Hisp**	**25**	**6/12/1994**	**M**	Mean	197.5	128.7	0.652	33.0	.	Yes	Yes	None

LN	STUDY	ID	Asthma Info	Smoke HX	Pks/day	Years Sm	Pks/yr	Ex	Type Ex	ExFreq (per/wk)	ExDuration (min	Meds	Processing
1	**VTG**	**014**	N/A	No	0	0	0	No	Sedentary	N/A	N/A	Atarax; Singulair	JO
2	**VTG**	**015**	N/A	No	0	0	0	Yes	Cycling	1	30.0	None	JO
3	**VTG**	**016**	N/A	No	0	0	0	Yes	Running	2	30.0	None	JO
6	**VTG**	**019**	N/A	No	0	0	0	Yes	Walking	4	30.0	Xyzal	JO
7	**VTG**	**020**	N/A	No	0	0	0	Yes	Running	3	20.0	None	JO
8	**VTG**	**021**	N/A	No	0	0	0	Yes	N/A	N/A	N/A	None	JO
9	**VTG**	**022**	N/A	No	0	0	0	Yes	Jump Rope	5	15.0	None	JO
10	**VTG**	**023**	N/A	No	0	0	0	.	Multiple	7	90.0	Synthroid; Yaz; Zyrtec	JO
11	**VTG**	**024**	N/A	No	0	0	0	Yes	Running	2	20.0	None	JO
12	**VTG**	**025**	N/A	No	0	0	0	Yes	Hiking	2	120.0	None	JO
14	**VTG**	**027**	N/A	No	No	0	0	Yes	Cycling	3.5	20.0	Concerta; Zyrtec	JO
15	**VTG**	**028**	.	.	.	.	.	.	.	.	.	.	JO
17	**VTG**	**030**	N/A	No	0	0	0	Yes	Weightlifting	N/A	N/A	None	JO
18	**VTG**	**031**	.	.	.	.	.	.	.	.	.	.	JO
19	**VTG**	**032**	N/A	No	0	0	0	Yes	Soccer	5	90.0	None	JO
20	**VTG**	**033**	N/A	No	0	0	0	Yes	Soccer	5	90.0	Tri Previfem	JO
21	**VTG**	**034**	N/A	No	0	0	0	Yes	Soccer	7	60.0	Vienva	JO
22	**VTG**	**035**	N/A	No	0	0	0	Yes	Cycling	3	30.0	None	JO
23	**VTG**	**036**	N/A	No	0	0	0	Yes	Dance	3	30.0	None	JO
24	**VTG**	**037**	N/A	No	0	0	0	Yes	Running	3	180.0	None	JO
25	**VTG**	**038**	N/A	No	0	0	0	Yes	Running	3	30.0	None	JO
26	**VTG**	**039**	N/A	No	0	0	0	Yes	Cycling	3	30.0	Birth Control	JO
28	**VTG**	**041**	N/A	No	0	0	0	No	N/A	N/A	N/A	Ibuprofen	JO
29	**VTG**	**042**	N/A	No	0	0	0	Yes	N/A	N/A	N/A	Buspirone; Lisinopril; Trazodone	JO

Screen Captures of Raw Data from VTG_{pred}:

ID	GRP	Code	TRIAL	P_B	Temp	RH	Mass (kg)	VTGp	VTG	ΔVTG (pred-meas)	VTGpp
014	OB	PRED	1	.	.	.	94.9	3.869	3.869	0.000	100.0
014	OB	PRED	2	.	.	.	94.9	3.869	3.869	0.000	100.0
014	OB	PRED	3	.	.	.	.	3.869	3.869	0.000	100.0
014	OB	PRED	Mean	.	.	.	94.86	3.869	3.869	0.000	100.0
015	OB	PRED	1	682.49	22.0	52.0	92.7	3.624	3.624	0.000	100.0
015	OB	PRED	2	682.49	22.0	52.0	92.7	3.624	3.624	0.000	100.0
015	OB	PRED	3	682.49	22.0	52.0	.	3.624	3.624	.	.
015	OB	PRED	Mean	682.49	22.0	52.0	92.71	3.624	3.624	0.000	100.0
016	NW	PRED	1	678.00	21.0	40.0	53.5	3.376	3.376	0.000	100.0
016	NW	PRED	2	678.00	21.0	40.0	53.5	3.376	3.376	0.000	100.0
016	NW	PRED	3	678.00	21.0	40.0	53.5	3.376	3.376	0.000	100.0
016	NW	PRED	Mean	678.00	21.0	40.0	53.47	3.376	3.376	0.000	100.0
019	OB	PRED	1	681.00	22.0	51.0	93.3	3.127	3.127	0.000	100.0
019	OB	PRED	2	681.00	22.0	51.0	93.1	3.127	3.127	0.000	100.0
019	OB	PRED	3	681.00	22.0	51.0	93.1	3.127	3.127	0.000	100.0
019	OB	PRED	Mean	681.00	22.0	51.0	93.17	3.127	3.127	0.000	100.0
020	NW	PRED	1	681.70	22.0	47.0	66.3	3.403	3.403	0.000	100.0
020	NW	PRED	2	681.70	22.0	47.0	66.3	3.403	3.403	0.000	100.0
020	NW	PRED	3	681.70	22.0	47.0	66.3	3.403	3.403	0.000	100.0
020	NW	PRED	Mean	681.70	22.0	47.0	66.35	3.403	3.403	0.000	100.0
021	NW	PRED	1	681.00	22.0	51.0	70.0	3.760	3.760	0.000	100.0
021	NW	PRED	2	681.00	22.0	51.0	70.0	3.760	3.760	0.000	100.0
021	NW	PRED	3	681.00	22.0	51.0	70.0	3.760	3.760	0.000	100.0
021	NW	PRED	Mean	681.00	22.0	51.0	70.03	3.760	3.760	0.000	100.0
022	NW	PRED	1	680.20	22.0	53.0	59.1	3.320	3.320	0.000	100.0
022	NW	PRED	2	680.20	22.0	53.0	59.1	3.320	3.320	0.000	100.0
022	NW	PRED	3	680.20	22.0	53.0	59.1	3.320	3.320	0.000	100.0
022	NW	PRED	Mean	680.20	22.0	53.0	59.12	3.320	3.320	0.000	100.0
023	NW	PRED	1	678.18	22.0	45.0	68.8	3.326	3.326	0.000	100.0
023	NW	PRED	2	678.18	22.0	45.0	68.8	3.326	3.326	0.000	100.0
023	NW	PRED	3	678.18	22.0	45.0	68.8	3.326	3.326	0.000	100.0
023	NW	PRED	Mean	678.18	22.0	45.0	68.82	3.326	3.326	0.000	100.0
024	OB	PRED	1	682.40	21.0	54.0	202.7	3.709	3.709	0.000	100.0
024	OB	PRED	2	682.40	21.0	54.0	202.7	3.709	3.709	0.000	100.0
024	OB	PRED	3	682.40	21.0	54.0	202.7	3.709	3.709	0.000	100.0
024	OB	PRED	Mean	682.40	21.0	54.0	202.70	3.709	3.709	0.000	100.0
025	OB	PRED	1	682.50	22.0	54.0	111.1	4.159	4.159	0.000	100.0
025	OB	PRED	2	682.50	22.0	54.0	111.1	4.159	4.159	0.000	100.0
025	OB	PRED	3	682.50	22.0	54.0	111.1	4.159	4.159	0.000	100.0
025	OB	PRED	Mean	682.50	22.0	54.0	111.07	4.159	4.159	0.000	100.0
027	NW	PRED	1	684.00	22.0	51.0	71.8	3.442	3.442	0.000	100.0
027	NW	PRED	2	684.00	22.0	51.0	71.8	3.442	3.442	0.000	100.0
027	NW	PRED	3	684.00	22.0	51.0	71.8	3.442	3.442	0.000	100.0
027	NW	PRED	Mean	684.00	22.0	51.0	71.82	3.442	3.442	0.000	100.0
028	NW	PRED	1	.	.	.	56.6	3.229	3.229	0.000	100.0
028	NW	PRED	2	.	.	.	56.7	3.229	3.229	0.000	100.0
028	NW	PRED	3	.	.	.	56.7	3.229	3.229	0.000	100.0
028	NW	PRED	Mean	#DIV/0!	#DIV/0!	#DIV/0!	56.67	3.229	3.229	0.000	100.0
030	OB	PRED	1	682.50	21.0	34.0	114.9	4.577	4.577	0.000	100.0
030	OB	PRED	2	682.50	21.0	34.0	115.0	4.577	4.577	0.000	100.0
030	OB	PRED	3	682.50	21.0	34.0	115.0	4.577	4.577	0.000	100.0
030	OB	PRED	Mean	682.50	21.0	34.0	114.97	4.577	4.577	0.000	100.0

ID	GRP	%BF	Δ%BF (pred-meas)	%FFM	FM (kg)	FFM (kg)	Body Volume	1st volume mst.	2nd volume mst.	3rd volume mst.	Density Model	Body Density	BSA	Processing
014	**OB**	27.80	-0.70	72.20	26.4	68.4933	91.567	89.109	89.155	.	Siri	1.036	21204.064	JO
014	**OB**	28.30	-1.20	71.70	26.8	68.0096	91.647	89.064	88.950	.	Siri	1.035	21202.851	JO
014	**OB**	.	.	.	.	.	.	.	.	.	Siri	.	.	JO
014	**OB**	28.05	-0.95	71.95	26.61	68.251	91.607	89.087	89.052	.	Siri	1.0355	21203.45757	JO
015	**OB**	38.50	2.00	61.50	35.7	57.0165	91.494	89.101	89.066	.	Siri	1.013	20566.140	JO
015	**OB**	39.40	2.70	60.60	36.5	56.1778	91.652	89.226	89.257	.	Siri	1.012	20564.470	JO
015	**OB**	.	.	.	.	.	.	.	.	.	Siri	.	.	JO
015	**OB**	38.95	2.35	61.05	36.11	56.59716337	91.573	89.164	89.162	#DIV/0!	Siri	1.012	20565.305	JO
016	**NW**	23.60	-0.90	76.40	12.6	40.8551	51.165	49.013	49.118	.	Siri	1.045	16105.696	JO
016	**NW**	22.60	-1.20	77.40	12.1	41.3861	51.054	48.718	48.943	48.961	Siri	1.047	16105.071	JO
016	**NW**	22.40	-1.50	77.60	12.0	41.4914	51.029	48.915	48.938	.	Siri	1.048	16104.803	JO
016	**NW**	22.86666667	-1.20	77.13	12.23	41.24422131	51.08266667	48.88212	48.9997	48.96071	Siri	1.046733333	16105.19006	JO
019	**OB**	38.80	0.50	61.20	36.2	57.1235	92.177	89.950	90.065	.	Siri	1.013	19669.237	JO
019	**OB**	39.50	2.20	60.50	36.8	56.3211	92.064	89.826	89.965	.	Siri	1.011	19647.162	JO
019	**OB**	39.50	2.10	60.50	36.8	56.3211	92.065	89.862	89.931	.	Siri	1.011	19647.159	JO
019	**OB**	39.26666667	1.60	60.73	36.59	56.58856602	92.102	89.87954	89.9872	#DIV/0!	Siri	1.011666667	19654.51928	JO
020	**NW**	27.30	0.80	72.70	18.1	48.2358	63.981	61.788	61.791	.	Siri	1.037	17780.187	JO
020	**NW**	27.10	0.40	72.90	18.0	48.3665	63.947	61.528	61.715	61.795	Siri	1.038	17779.878	JO
020	**NW**	26.60	0.30	73.40	17.6	48.6952	63.879	61.605	61.770	.	Siri	1.039	17779.406	JO
020	**NW**	27	0.50	73.00	17.91	48.43247606	63.93566667	61.64008	61.7589	61.79542	Siri	1.0377	17779.82375	JO
021	**NW**	15.20	-1.30	84.77	10.6	59.3410	65.788	63.417	63.425	.	Siri	1.064	18481.255	JO
021	**NW**	14.00	-5.00	85.98	9.8	60.2250	65.666	63.230	63.367	.	Siri	1.067	18486.949	JO
021	**NW**	14.60	-6.70	85.38	10.2	59.8000	65.742	63.319	63.430	.	Siri	1.064	18485.937	JO
021	**NW**	14.6	-4.33	85.38	10.22	59.78866667	65.732	63.32205	63.40718	#DIV/0!	Siri	1.064933333	18484.7138	JO
022	**NW**	18.20	-2.10	81.80	10.8	48.3560	55.919	53.817	53.835	.	Siri	1.057	16373.366	JO
022	**NW**	17.50	-3.60	82.50	10.3	48.7726	55.833	53.711	53.769	.	Siri	1.059	16373.767	JO
022	**NW**	17.80	-2.00	82.20	10.5	48.5939	55.866	53.801	53.746	.	Siri	1.058	16373.565	JO
022	**NW**	17.83333333	-2.57	82.17	10.54	48.57416004	55.87266667	53.77644	53.78349	#DIV/0!	Siri	1.0581	16373.56602	JO
023	**NW**	31.60	-1.30	68.40	21.7	47.0746	66.962	64.723	65.062	64.880	Siri	1.028	17775.116	JO
023	**NW**	31.80	-0.20	68.20	21.9	46.9355	66.986	64.834	64.816	.	Siri	1.027	17774.894	JO
023	**NW**	31.00	-0.60	69.00	21.3	47.4861	66.877	64.660	64.774	.	Siri	1.029	17774.887	JO
023	**NW**	31.46666667	-0.70	68.53	21.66	47.16539824	66.94166667	64.73892	64.88397	64.8802	Siri	1.0281	17774.96553	JO
024	**OB**	30.00	1.00	31.75	27.6	64.3640	89.168	86.767	86.677	.	Siri	1.031	20615.535	JO
024	**OB**	29.60	0.90	31.91	27.3	64.6900	89.097	86.629	86.673	.	Siri	1.032	20615.096	JO
024	**OB**	29.10	0.40	32.18	26.7	65.2090	89.168	86.538	86.526	.	Siri	1.033	20613.854	JO
024	**OB**	29.56666667	0.77	31.95	27.19	64.75433333	89.14433333	86.64479	86.62514	#DIV/0!	Siri	1.032133333	20614.82848	JO
025	**OB**	31.60	0.60	68.40	35.1	75.9685	108.058	105.212	105.408	.	Siri	1.028	23218.897	JO
025	**OB**	32.10	1.80	67.90	35.7	75.4158	108.168	105.407	105.433	.	Siri	1.027	23219.243	JO
025	**OB**	31.90	1.10	68.10	35.4	75.6382	108.132	105.465	105.304	.	Siri	1.027	23219.282	JO
025	**OB**	31.86666667	1.17	68.13	35.39	75.67415194	108.1193333	105.3613	105.3815	#DIV/0!	Siri	1.027266667	23219.14038	JO
027	**NW**	25.70	0.20	74.30	18.5	53.3720	69.039	66.759	66.838	.	Siri	1.041	18491.676	JO
027	**NW**	24.90	-0.70	75.10	17.9	53.9405	68.908	66.569	66.766	.	Siri	1.042	18490.779	JO
027	**NW**	25.60	0.40	74.40	18.4	53.4269	68.997	66.685	66.829	.	Siri	1.041	18489.198	JO
027	**NW**	25.4	-0.03	74.60	18.24	53.57979332	68.98133333	66.67115	66.81077	#DIV/0!	Siri	1.0412	18490.55099	JO
028	**NW**	22.80	1.20	77.20	12.9	43.7292	54.102	52.009	52.089	.	Siri	1.047	16292.293	JO
028	**NW**	22.70	0.30	77.30	12.9	43.8221	54.131	52.138	52.019	.	Siri	1.047	16298.026	JO
028	**NW**	22.80	1.20	77.20	12.9	43.7602	54.142	52.155	52.024	.	Siri	1.047	16297.192	JO
028	**NW**	22.76666667	0.90	77.23	12.90	43.77049002	54.125	52.10083	52.04397	#DIV/0!	Siri	1.047066667	16295.83736	JO
030	**OB**	28.10	-0.30	71.90	32.3	82.6451	111.016	108.186	107.916	.	Siri	1.035	24358.252	.
030	**OB**	28.30	-1.40	71.70	32.5	82.4518	111.122	108.165	108.150	.	Siri	1.035	24362.854	.
030	**OB**	30.80	2.40	69.20	35.4	79.5654	111.676	108.859	108.556	.	Siri	1.030	24361.350	.
030	**OB**	29.06666667	0.23	70.93	33.42	81.55408979	111.2713333	108.4034	108.2073	#DIV/0!	Siri	1.0333	24360.81845	.

ID	GRP	Code	TRIAL	P_B	Temp	RH	Mass (kg)	VTGp	VTG	ΔVTG (pred-meas)	VTGpp
031	**NW**	**PRED**	**1**	.	.	.	69.9	3.310	3.310	0.000	100.0
031	**NW**	**PRED**	**2**	.	.	.	69.9	3.310	3.310	0.000	100.0
031	**NW**	**PRED**	**3**	.	.	.	69.9	3.310	3.310	0.000	100.0
031	**NW**	**PRED**	**Mean**	#DIV/0!	#DIV/0!	#DIV/0!	69.93	3.310	3.310	0.000	100.0
032	**NW**	**PRED**	**1**	683.00	23.0	52.0	64.7	3.220	3.220	0.000	100.0
032	**NW**	**PRED**	**2**	683.00	23.0	52.0	64.7	3.220	3.220	0.000	100.0
032	**NW**	**PRED**	**3**	683.00	23.0	52.0	64.7	3.220	3.220	0.000	100.0
032	**NW**	**PRED**	**Mean**	683.00	23.0	52.0	64.73	3.220	3.220	0.000	100.0
033	**NW**	**PRED**	**1**	683.00	23.0	52.0	53.5	3.050	3.050	0.000	100.0
033	**NW**	**PRED**	**2**	683.00	23.0	52.0	53.5	3.050	3.050	0.000	100.0
033	**NW**	**PRED**	**3**	683.00	23.0	52.0	53.5	3.050	3.050	0.000	100.0
033	**NW**	**PRED**	**Mean**	683.00	23.0	52.0	53.49	3.050	3.050	0.000	100.0
034	**NW**	**PRED**	**1**	684.00	22.0	53.0	55.0	3.132	3.132	0.000	100.0
034	**NW**	**PRED**	**2**	684.00	22.0	53.0	55.0	3.132	3.132	0.000	100.0
034	**NW**	**PRED**	**3**	684.00	22.0	53.0	55.0	3.132	3.132	0.000	100.0
034	**NW**	**PRED**	**Mean**	684.00	22.0	53.0	54.96	3.132	3.132	0.000	100.0
035	**OB**	**PRED**	**1**	680.20	22.0	52.0	98.4	4.115	4.115	0.000	100.0
035	**OB**	**PRED**	**2**	680.20	22.0	52.0	98.4	4.115	4.115	0.000	100.0
035	**OB**	**PRED**	**3**	680.20	22.0	52.0	98.3	4.115	4.115	0.000	100.0
035	**OB**	**PRED**	**Mean**	680.20	22.0	52.0	98.35	4.115	4.115	0.000	100.0
036	**NW**	**PRED**	**1**	680.30	22.0	53.0	52.2	2.818	2.818	0.000	100.0
036	**NW**	**PRED**	**2**	680.30	22.0	53.0	52.1	2.818	2.818	0.000	100.0
036	**NW**	**PRED**	**3**	680.30	22.0	53.0	52.1	2.818	2.818	0.000	100.0
036	**NW**	**PRED**	**Mean**	680.30	22.0	53.0	52.15	2.818	2.818	0.000	100.0
037	**NW**	**PRED**	**1**	.	.	.	65.0	3.592	3.592	0.000	100.0
037	**NW**	**PRED**	**2**	.	.	.	65.0	3.592	3.592	0.000	100.0
037	**NW**	**PRED**	**3**	.	.	.	65.0	3.592	3.592	0.000	100.0
037	**NW**	**PRED**	**Mean**	#DIV/0!	#DIV/0!	#DIV/0!	64.99	3.592	3.592	0.000	100.0
038	**NW**	**PRED**	**1**	.	.	.	68.1	3.615	3.615	0.000	100.0
038	**NW**	**PRED**	**2**	.	.	.	68.1	3.615	3.615	0.000	100.0
038	**NW**	**PRED**	**3**	.	.	.	68.0	3.615	3.615	0.000	100.0
038	**NW**	**PRED**	**Mean**	#DIV/0!	#DIV/0!	#DIV/0!	68.06	3.615	3.615	0.000	100.0
039	**NW**	**PRED**	**1**	688.00	22.00	53.0	60.9	3.300	3.300	0.000	100.0
039	**NW**	**PRED**	**2**	688.00	22.00	53.0	60.9	3.300	3.300	0.000	100.0
039	**NW**	**PRED**	**3**	688.00	22.00	53.0	60.9	3.300	3.300	0.000	100.0
039	**NW**	**PRED**	**Mean**	688.00	22.0	53.0	60.90	3.300	3.300	0.000	100.0
041	**OB**	**PRED**	**1**	697.45	22.0	46.0	106.2	3.938	3.938	0.000	100.0
041	**OB**	**PRED**	**2**	697.45	22.0	46.0	106.1	3.938	3.938	0.000	100.0
041	**OB**	**PRED**	**3**	697.45	22.0	46.0	106.1	3.938	3.938	0.000	100.0
041	**OB**	**PRED**	**Mean**	697.45	22.0	46.0	106.14	3.938	3.938	0.000	100.0
042	**OB**	**PRED**	**1**	679.45	21.0	51.0	128.7	4.860	4.860	0.000	100.0
042	**OB**	**PRED**	**2**	679.45	21.0	51.0	128.7	4.860	4.860	0.000	100.0
042	**OB**	**PRED**	**3**	679.45	21.0	51.0	128.7	4.860	4.860	0.000	100.0
042	**OB**	**PRED**	**Mean**	679.45	21.0	51.0	128.69	4.860	4.860	0.000	100.0

ID	GRP	%BF	Δ%BF (pred-meas)	%FFM	FM (kg)	FFM (kg)	Body Volume	1st volume mst.	2nd volume mst.	3rd volume mst.	Density Model	Body Density	BSA	Processing
031	**NW**	32.90	1.00	67.10	23.0	46.9223	68.221	66.100	66.021	.	Siri	1.025	17911.499	JO
031	**NW**	32.70	-1.20	67.30	22.9	47.0645	68.196	66.043	66.028	.	Siri	1.026	17911.884	JO
031	**NW**	32.60	0.10	67.40	22.8	47.1353	68.187	66.019	66.034	.	Siri	1.026	17912.012	JO
031	**NW**	32.73333333	-0.03	67.27	22.89	47.0407023	68.20133333	66.05398	66.02775	#DIV/0!	Siri	1.025366667	17911.79819	JO
032	**NW**	20.20	0.60	79.80	13.1	51.6566	61.494	59.363	59.437	.	Siri	1.053	17243.235	JO
032	**NW**	20.80	0.20	79.20	13.5	51.2664	61.565	59.435	59.508	.	Siri	1.051	17242.987	JO
032	**NW**	20.30	-0.40	79.70	13.1	51.5879	61.501	59.437	59.380	.	Siri	1.053	17242.672	JO
032	**NW**	20.43333333	0.13	79.57	13.23	51.50361873	61.52	59.41162	59.44196	#DIV/0!	Siri	1.052266667	17242.96477	JO
033	**NW**	27.40	0.20	72.63	14.6	38.8490	1.037	49.594	49.680	.	Siri	1.037	15573.620	JO
033	**NW**	26.60	1.20	73.36	14.3	39.2440	1.039	49.520	49.607	.	Siri	1.039	15574.268	JO
033	**NW**	27.60	1.00	72.44	14.6	38.7470	1.037	49.663	49.451	49.662	Siri	1.037	15574.144	JO
033	**NW**	27.2	0.80	72.81	14.51	38.94666667	1.0373	49.59229	49.57935	49.66228	Siri	1.0373	15574.01072	JO
034	**NW**	20.40	0.60	79.60	11.2	43.7554	52.233	50.264	50.211	.	Siri	1.052	15910.310	JO
034	**NW**	18.90	-1.20	81.10	10.4	44.5707	52.057	50.044	50.078	.	Siri	1.056	15908.902	JO
034	**NW**	19.80	0.00	80.20	10.9	44.0753	52.155	50.120	50.199	.	Siri	1.054	15908.781	JO
034	**NW**	19.7	-0.20	80.30	10.83	44.13379711	52.14833333	50.14274	50.16244	#DIV/0!	Siri	1.053933333	15909.33096	JO
035	**OB**	30.30	1.00	69.70	29.8	68.5572	95.441	92.782	92.763	.	Siri	1.031	21893.034	JO
035	**OB**	30.80	2.80	69.20	30.3	68.0654	95.541	92.851	92.895	.	Siri	1.030	21893.022	JO
035	**OB**	30.20	2.20	69.80	29.7	68.6406	95.407	92.862	92.616	.	Siri	1.031	21891.003	JO
035	**OB**	30.43333333	2.00	69.57	29.93	68.42107583	95.463	92.83177	92.75803	#DIV/0!	Siri	1.030266667	21892.35306	JO
036	**NW**	25.10	0.70	74.90	13.1	39.0618	50.060	48.195	48.276	.	Siri	1.042	14934.701	JO
036	**NW**	24.30	1.80	75.70	12.7	39.4743	49.970	48.124	48.166	.	Siri	1.044	14933.945	JO
036	**NW**	23.90	0.50	76.10	12.5	39.6818	49.920	48.098	48.511	48.093	Siri	1.045	14933.779	JO
036	**NW**	24.43333333	1.00	75.57	12.74	39.40594732	49.98333333	48.13904	48.31775	48.09334	Siri	1.0433	14934.14182	JO
037	**NW**	16.90	0.70	83.10	11.0	53.9771	61.271	59.033	58.991	.	Siri	1.060	17605.447	JO
037	**NW**	15.30	1.00	84.70	9.9	55.0621	61.108	58.937	59.128	58.761	Siri	1.064	17611.668	JO
037	**NW**	16.00	1.20	84.00	10.4	54.5997	61.186	58.751	58.943	58.910	Siri	1.062	17610.655	JO
037	**NW**	16.06666667	0.97	83.93	10.44	54.54628063	61.18833333	58.90701	59.02101	58.83583	Siri	1.062066667	17609.25696	JO
038	**NW**	32.10	3.20	67.90	21.8	46.2071	66.283	64.003	63.990	.	Siri	1.027	17995.514	JO
038	**NW**	32.30	4.20	67.70	22.0	46.0893	66.339	63.980	64.124	.	Siri	1.026	17998.564	JO
038	**NW**	31.70	3.20	68.30	21.6	46.4751	66.219	63.673	64.009	63.856	Siri	1.028	17994.818	JO
038	**NW**	32.03333333	3.53	67.97	21.80	46.257156	66.28033333	63.8851	64.04109	63.85556	Siri	1.026833333	17996.29865	JO
039	**NW**	35.70	3.00	64.30	21.7	39.1455	59.737	57.609	57.807	57.643	Siri	1.019	16945.381	JO
039	**NW**	36.70	4.30	63.30	22.4	38.5542	59.888	57.767	57.785	.	Siri	1.017	16948.655	JO
039	**NW**	35.90	4.20	64.10	21.9	39.0377	59.778	57.639	57.694	.	Siri	1.019	16947.967	JO
039	**NW**	36.1	3.83	63.90	21.98	38.91248605	59.801	57.67162	57.76205	57.64333	Siri	1.0183	16947.33433	JO
041	**OB**	36.10	-1.80	63.90	38.3	67.8323	104.242	101.512	101.732	.	Siri	1.018	22378.278	JO
041	**OB**	37.40	0.40	62.60	39.7	66.4426	104.518	101.982	101.814	.	Siri	1.016	22376.890	JO
041	**OB**	37.10	0.70	62.90	39.4	66.7558	104.428	101.790	101.826	.	Siri	1.016	22376.150	JO
041	**OB**	36.86666667	-0.23	63.13	39.13	67.01023101	104.396	101.7614	101.7906	#DIV/0!	Siri	1.0167	22377.10626	JO
042	**OB**	32.30	-0.70	67.70	41.6	87.1264	125.404	122.074	122.405	.	Siri	1.026	26134.599	JO
042	**OB**	32.10	-0.50	67.90	41.3	87.3809	125.340	122.246	122.105	.	Siri	1.027	26134.240	JO
042	**OB**	32.00	0.80	68.00	41.2	87.5021	125.297	122.049	122.217	.	Siri	1.027	26133.284	JO
042	**OB**	32.13333333	-0.13	67.87	41.35	87.33644838	125.347	122.123	122.2425	#DIV/0!	Siri	1.026633333	26134.04079	JO

Screen Captures of Raw Data from VTG_{meas}:

ID	GRP	Code	Order	TRIAL	Mass (kg)	VTGp	VTG	ΔVTG (pred-meas)	VTGpp
014	OB	MS	2	1	94.9	3.869	4.099	-0.230	105.9
014	OB	MS	2	2	94.8	3.869	4.295	-0.426	111.0
014	OB	MS	2	3	.	3.869	.	.	.
014	OB	MS	2	Mean	94.85	3.869	4.197	-0.328	108.5
015	OB	MS	1	1	92.7	3.624	2.167	1.457	59.8
015	OB	MS	1	2	92.7	3.624	2.386	1.238	65.8
015	OB	MS	1	3	.	3.624	.	.	.
015	OB	MS	1	Mean	92.69	3.624	2.277	1.348	62.8
016	NW	MS	2	1	53.5	3.376	3.933	-0.557	116.5
016	NW	MS	2	2	53.5	3.376	4.015	-0.639	118.9
016	NW	MS	2	3	53.4	3.376	3.937	-0.561	116.6
016	NW	MS	2	Mean	53.46	3.376	3.962	-0.586	117.3
019	OB	MS	2	1	93.1	3.127	2.373	0.754	75.9
019	OB	MS	2	2	93.1	3.127	2.130	0.997	68.1
019	OB	MS	2	3	93.1	3.127	2.279	0.848	72.9
019	OB	MS	2	Mean	93.07	3.127	2.261	0.866	72.3
020	NW	MS	.	1	66.3	3.403	3.086	0.317	90.7
020	NW	MS	.	2	66.3	3.403	3.314	0.089	97.4
020	NW	MS	.	3	66.3	3.403	3.205	0.198	94.2
020	NW	MS	.	Mean	66.33	3.403	3.202	0.201	94.1
021	NW	MS	.	1	69.9	3.760	4.995	-1.235	132.8
021	NW	MS	.	2	70.0	3.760	5.003	-1.243	133.1
021	NW	MS	.	3	70.0	3.760	5.700	-1.940	151.6
021	NW	MS	.	Mean	69.96	3.760	5.233	-1.473	139.2
022	NW	MS	2	1	59.1	3.320	4.223	-0.903	127.2
022	NW	MS	2	2	59.1	3.320	4.284	-0.964	129.0
022	NW	MS	2	3	59.1	3.320	4.128	-0.808	124.3
022	NW	MS	2	Mean	59.13	3.320	4.212	-0.892	126.9
023	NW	MS	2	1	68.8	3.326	3.762	-0.436	113.1
023	NW	MS	2	2	68.8	3.326	3.373	-0.047	101.4
023	NW	MS	2	3	68.8	3.326	3.395	-0.069	102.1
023	NW	MS	2	Mean	68.80	3.326	3.510	-0.184	105.5
024	OB	MS	2	1	91.9	3.709	3.554	0.155	95.8
024	OB	MS	2	2	91.9	3.709	3.554	0.155	95.8
024	OB	MS	2	3	91.9	3.709	3.687	0.022	99.4
024	OB	MS	2	Mean	91.90	3.709	3.598	0.111	97.0
025	OB	MS	2	1	111.1	4.159	3.963	0.196	95.3
025	OB	MS	2	2	111.1	4.159	3.772	0.387	90.7
025	OB	MS	2	3	111.0	4.159	3.991	0.168	96.0
025	OB	MS	2	Mean	111.05	4.159	3.909	0.250	94.0
027	NW	MS	2	1	72.0	3.442	3.405	0.037	98.9
027	NW	MS	2	2	72.0	3.442	3.177	0.265	92.3
027	NW	MS	2	3	72.0	3.442	3.418	0.024	99.3
027	NW	MS	2	Mean	71.96	3.442	3.333	0.109	96.8
028	NW	MS	2	1	56.7	3.229	2.959	0.270	91.6
028	NW	MS	2	2	56.7	3.229	3.089	0.140	95.7
028	NW	MS	2	3	56.7	3.229	2.960	0.269	91.7
028	NW	MS	2	Mean	56.68	3.229	3.003	0.226	93.0
030	OB	MS	2	1	114.9	4.577	3.998	0.579	87.3
030	OB	MS	2	2	115.0	4.577	4.932	-0.355	107.8
030	OB	MS	2	3	115.0	4.577	4.694	-0.117	102.6
030	OB	MS	2	Mean	114.97	4.577	4.541	0.036	99.2

ID	GRP	%BF	Δ%BF (pred-meas)	%FFM	FM (kg)	FFM (kg)	Body Volume	1st volume mst.	2nd volume mst.	3rd volume mst.	Density Model	Body Density	BSA	Processing
014	**OB**	28.50	-0.70	71.50	27.0	67.8331	91.716	89.121	89.052	.	Siri	1.034	21204.569	JO
014	**OB**	29.50	-1.20	70.50	28.0	66.8574	91.869	89.135	89.186	.	Siri	1.032	21200.935	JO
014	**OB**	.	.	.	.	.	.	.	.	.	Siri	.	.	JO
014	**OB**	29	-0.95	71.00	27.51	67.34521204	91.7925	89.12795	89.1189	#DIV/0!	Siri	1.03335	21202.75218	JO
015	**OB**	36.50	2.00	63.50	33.8	58.8622	91.101	88.868	89.261	89.288	Siri	1.018	20564.876	JO
015	**OB**	36.70	2.70	63.30	34.0	58.6715	91.138	88.886	89.178	89.269	Siri	1.017	20564.088	JO
015	**OB**	.	.	.	.	.	.	.	.	.	Siri	.	.	JO
015	**OB**	36.6	2.35	63.40	33.93	58.76685027	91.1195	88.87697	89.21948	89.27818	#DIV/0!	1.01725	20564.48207	JO
016	**NW**	24.50	-0.90	75.50	13.1	40.3675	51.249	48.912	48.936	.	Siri	1.014	16104.624	JO
016	**NW**	23.80	-1.20	76.20	12.7	40.7360	51.172	48.777	48.851	.	Siri	1.045	16103.656	JO
016	**NW**	23.90	-1.50	76.10	12.8	40.6747	51.175	48.868	48.828	.	Siri	1.044	16102.337	JO
016	**NW**	24.06666667	-1.20	75.93	12.87	40.59277016	51.19866667	48.85212	48.87194	#DIV/0!	#DIV/0!	1.034466667	16103.53895	JO
019	**OB**	38.30	0.50	61.70	35.6	57.4264	91.819	89.709	90.020	89.884	Siri	1.014	19645.437	JO
019	**OB**	37.30	2.20	62.70	34.7	58.3532	91.613	89.857	89.831	.	Siri	1.016	19644.884	JO
019	**OB**	37.40	2.10	62.60	34.8	58.2532	91.620	89.790	89.792	.	Siri	1.016	19643.880	JO
019	**OB**	37.66666667	1.60	62.33	35.05	58.01091753	91.684	89.78528	89.88111	89.88407	#DIV/0!	1.0151	19644.73392	JO
020	**NW**	26.50	0.80	73.50	17.6	48.7552	63.860	61.507	61.779	61.811	Siri	1.039	17778.429	JO
020	**NW**	26.70	0.40	73.30	17.7	48.6206	63.878	61.730	61.715	.	Siri	1.038	17778.128	JO
020	**NW**	26.30	0.30	73.70	17.4	48.8830	63.827	61.717	61.713	.	Siri	1.039	17777.676	JO
020	**NW**	26.5	0.50	73.50	17.58	48.75294419	63.855	61.65128	61.73556	61.81133	Siri	1.038766667	17778.07774	JO
021	**NW**	16.50	-1.30	83.48	11.5	58.3870	65.916	62.978	63.133	.	Siri	1.061	18474.752	JO
021	**NW**	19.00	-5.00	81.00	13.3	56.6760	66.295	63.415	63.646	63.447	Siri	1.055	18478.103	JO
021	**NW**	21.30	-6.70	78.70	14.9	55.0595	66.614	63.457	63.485	.	Siri	1.050	18477.075	JO
021	**NW**	18.93333333	-4.33	81.06	13.25	56.70748188	66.275	63.2831	63.42117	63.44747	Siri	1.055566667	18476.64355	JO
022	**NW**	20.30	-2.10	79.70	12.0	47.1320	56.191	53.791	53.684	.	Siri	1.052	16375.934	JO
022	**NW**	21.10	-3.60	78.90	12.5	46.6524	56.273	53.830	53.759	.	Siri	1.051	16374.970	JO
022	**NW**	19.80	-2.00	80.20	11.7	47.4158	56.114	53.664	53.732	.	Siri	1.054	16374.200	JO
022	**NW**	20.4	-2.57	79.60	12.06	47.06675138	56.19266667	53.762	53.72499	#DIV/0!	Siri	1.052233333	16375.03469	JO
023	**NW**	32.90	-1.30	67.10	22.6	46.1686	67.130	64.718	64.873	.	Siri	1.025	17773.272	JO
023	**NW**	32.00	-0.20	68.00	22.0	46.7868	66.999	64.790	64.850	.	Siri	1.027	17773.095	JO
023	**NW**	31.60	-0.60	68.40	21.7	47.0573	66.939	64.717	64.785	.	Siri	1.028	17772.349	JO
023	**NW**	32.16666667	-0.70	67.83	22.13	46.67090287	67.02266667	64.74178	64.83581	#DIV/0!	Siri	1.026566667	17772.90509	JO
024	**OB**	29.00	1.00	71.05	26.7	65.3120	88.947	86.611	86.516	.	Siri	1.034	20612.990	JO
024	**OB**	28.70	0.90	71.33	26.4	65.5460	88.860	86.481	86.471	.	Siri	1.034	20609.571	JO
024	**OB**	28.70	0.40	71.30	26.4	65.5145	88.868	86.414	86.448	.	Siri	1.034	20609.014	JO
024	**OB**	28.8	0.77	71.23	26.47	65.45749372	88.89166667	86.50178	86.47821	#DIV/0!	Siri	1.033866667	20610.52538	JO
025	**OB**	31.00	0.60	69.00	34.4	76.6263	107.913	105.222	105.264	.	Siri	1.029	23217.797	JO
025	**OB**	30.30	1.80	69.70	33.6	77.4043	107.752	105.033	105.284	.	Siri	1.031	23217.879	JO
025	**OB**	30.80	1.10	69.20	34.2	76.8400	107.846	105.183	105.146	.	Siri	1.030	23216.720	JO
025	**OB**	30.7	1.17	69.30	34.09	76.95688713	107.837	105.1462	105.2317	#DIV/0!	Siri	1.029766667	23217.46539	JO
027	**NW**	25.50	0.20	74.50	18.4	53.6185	69.133	66.986	66.828	.	Siri	1.041	18506.779	JO
027	**NW**	25.60	-0.70	74.40	18.4	53.5393	69.136	66.998	67.003	.	Siri	1.041	18505.712	JO
027	**NW**	25.20	0.40	74.80	18.1	53.8244	69.076	66.920	66.768	.	Siri	1.042	18505.306	JO
027	**NW**	25.43333333	-0.03	74.57	18.30	53.66072741	69.115	66.96815	66.86609	#DIV/0!	Siri	1.041233333	18505.93208	JO
028	**NW**	21.60	1.20	78.40	12.2	44.4410	54.008	52.065	52.061	.	Siri	1.050	16297.299	JO
028	**NW**	22.40	0.30	77.60	12.7	43.9816	54.088	52.105	52.078	.	Siri	1.048	16296.361	JO
028	**NW**	21.60	1.20	78.40	12.2	44.4386	53.999	52.091	52.017	.	Siri	1.050	16296.915	JO
028	**NW**	21.86666667	0.90	78.13	12.39	44.28707758	54.03166667	52.08695	52.05217	#DIV/0!	Siri	1.049066667	16296.85816	JO
030	**OB**	28.40	-0.30	71.60	32.6	82.2747	111.051	108.399	108.230	.	Siri	1.035	24355.035	JO
030	**OB**	29.70	-1.40	70.30	34.2	80.8622	111.460	108.483	108.216	.	Siri	1.032	24365.451	JO
030	**OB**	28.40	2.40	71.60	32.6	82.3135	111.103	107.980	108.195	.	Siri	1.035	24359.916	JO
030	**OB**	28.83333333	0.23	71.17	33.15	81.81676653	111.2046667	108.2874	108.2136	#DIV/0!	Siri	1.0338	24360.13401	JO

ID	GRP	Code	Order	TRIAL	Mass (kg)	VTGp	VTG	ΔVTG (pred-meas)	VTGpp
031	NW	MS	2	1	70.0	3.310	3.220	0.090	97.3
031	NW	MS	2	2	69.9	3.310	3.637	-0.327	109.9
031	NW	MS	2	3	69.9	3.310	3.264	0.046	98.6
031	NW	MS	2	Mean	69.95	3.310	3.374	-0.064	101.9
032	NW	MS	2	1	64.7	3.220	3.267	-0.047	101.5
032	NW	MS	2	2	64.7	3.220	3.284	-0.064	102.0
032	NW	MS	2	3	64.7	3.220	3.227	-0.007	100.2
032	NW	MS	2	Mean	64.75	3.220	3.259	-0.039	101.2
033	NW	MS	2	1	53.5	3.050	2.802	0.248	91.9
033	NW	MS	2	2	53.5	3.050	2.657	0.393	87.1
033	NW	MS	2	3	53.5	3.050	2.723	0.327	89.3
033	NW	MS	2	Mean	53.52	3.050	2.727	0.323	89.4
034	OB	MS	2	1	55.0	3.132	3.320	-0.188	106.0
034	OB	MS	2	2	54.9	3.132	3.424	-0.292	109.3
034	OB	MS	2	3	54.9	3.132	3.311	-0.179	105.7
034	OB	MS	2	Mean	54.94	3.132	3.352	-0.220	107.0
035	OB	MS	2	1	98.3	4.115	3.143	0.972	76.4
035	OB	MS	2	2	98.3	4.115	2.683	1.432	65.2
035	OB	MS	2	3	98.3	4.115	2.878	1.237	69.9
035	OB	MS	2	Mean	98.31	4.115	2.901	1.214	70.5
036	NW	MS	2	1	52.2	2.818	2.364	0.454	83.9
036	NW	MS	2	2	52.2	2.818	2.096	0.722	74.4
036	NW	MS	2	3	52.2	2.818	2.385	0.433	84.6
036	NW	MS	2	Mean	52.16	2.818	2.282	0.536	81.0
037	NW	MS	2	1	65.0	3.592	3.852	-0.260	107.2
037	NW	MS	2	2	65.0	3.592	3.457	0.135	96.2
037	NW	MS	2	3	65.0	3.592	3.784	-0.192	105.3
037	NW	MS	2	Mean	64.98	3.592	3.698	-0.106	102.9
038	NW	MS	2	1	68.0	3.615	3.013	0.602	83.3
038	NW	MS	2	2	68.1	3.615	2.950	0.665	81.6
038	NW	MS	2	3	68.0	3.615	2.911	0.704	80.5
038	NW	MS	2	Mean	68.04	3.615	2.958	0.657	81.8
039	NW	MS	2	1	61.0	3.300	2.225	1.075	67.4
039	NW	MS	2	2	61.0	3.300	2.163	1.137	65.5
039	NW	MS	2	3	61.0	3.300	2.204	1.096	66.8
039	NW	MS	2	Mean	60.99	3.300	2.197	1.103	66.6
041	OB	MS	2	1	106.1	3.938	3.956	-0.018	100.5
041	OB	MS	2	2	106.1	3.938	3.627	0.311	92.1
041	OB	MS	2	3	106.1	3.938	3.699	0.239	93.9
041	OB	MS	2	Mean	106.12	3.938	3.761	0.177	95.5
042	OB	MS	2	1	128.7	4.860	5.300	-0.440	109.1
042	OB	MS	2	2	128.7	4.860	4.986	-0.126	102.6
042	OB	MS	2	3	128.6	4.860	3.963	0.897	81.5
042	OB	MS	2	Mean	128.65	4.86	4.750	0.110	97.7

ID	GRP	%BF	Δ%BF (pred-meas)	%FFM	FM (kg)	FFM (kg)	Body Volume	1st volume mst.	2nd volume mst.	3rd volume mst.	Density Model	Body Density	BSA	Processing
031	**NW**	31.90	1.00	68.10	22.3	47.6418	68.107	66.067	65.898	.	Siri	1.027	17914.730	JO
031	**NW**	33.90	-1.20	66.10	23.7	46.2333	68.374	66.061	66.105	.	Siri	1.023	17913.201	JO
031	**NW**	32.50	0.10	67.50	22.7	47.2123	68.177	66.049	66.021	.	Siri	1.026	17913.160	JO
031	**NW**	32.76666667	-0.03	67.23	22.92	47.02915708	68.21933333	66.05884	66.00826	#DIV/0!	Siri	1.025366667	17913.69683	JO
032	**NW**	19.60	0.60	80.40	12.7	52.0586	61.429	59.667	59.290	59.344	Siri	1.054	17245.159	JO
032	**NW**	20.60	0.20	79.40	13.3	51.4088	61.550	59.487	59.375	.	Siri	1.052	17244.830	JO
032	**NW**	20.70	-0.40	79.30	13.4	51.3395	61.563	59.545	59.389	.	Siri	1.052	17244.182	JO
032	**NW**	20.3	0.13	79.70	13.14	51.6023208	61.514	59.56633	59.3514	59.34392	Siri	1.052533333	17244.72338	JO
033	**NW**	27.20	0.20	72.80	14.6	38.9720	51.606	49.604	49.783	49.732	Siri	1.037	15579.009	JO
033	**NW**	25.40	1.20	74.60	13.6	39.9291	51.400	49.642	49.577	.	Siri	1.041	15577.935	JO
033	**NW**	26.60	1.00	73.40	14.2	39.2801	51.524	49.630	49.785	.	Siri	1.039	15576.794	JO
033	**NW**	26.4	0.80	73.60	14.13	39.39372777	51.51	49.62534	49.71488	49.73238	Siri	1.039066667	15577.91267	JO
034	**OB**	19.80	0.60	80.20	10.9	44.0751	52.161	49.521	50.023	50.158	Siri	1.054	15908.758	JO
034	**OB**	20.10	-1.20	79.90	11.0	43.8979	52.180	50.239	50.026	50.110	Siri	1.053	15906.859	JO
034	**OB**	19.80	0.00	80.20	10.9	44.0566	52.135	50.092	50.044	.	Siri	1.054	15905.913	JO
034	**OB**	19.9	-0.20	80.10	10.93	44.00987879	52.15866667	49.95067	50.03104	50.1339	Siri	1.0534	15907.17669	JO
035	**OB**	29.30	1.00	70.70	28.8	69.5170	95.207	92.913	92.942	.	Siri	1.033	21889.838	JO
035	**OB**	28.00	2.80	72.00	27.5	70.7813	94.932	92.818	92.854	.	Siri	1.036	21888.006	JO
035	**OB**	28.00	2.20	72.00	27.5	70.7676	94.921	92.721	92.774	.	Siri	1.036	21886.211	JO
035	**OB**	28.43333333	2.00	71.57	27.95	70.35528577	95.02	92.8174	92.8567	#DIV/0!	Siri	1.034633333	21888.01827	JO
036	**NW**	24.40	0.70	75.60	12.7	39.4422	49.996	48.420	48.287	.	Siri	48.420	14937.169	JO
036	**NW**	22.50	1.80	77.50	11.7	40.4247	49.789	48.469	48.278	48.229	Siri	48.469	14935.797	JO
036	**NW**	23.40	0.50	76.60	12.2	39.9524	49.882	48.306	48.155	.	Siri	48.306	14935.343	JO
036	**NW**	23.43333333	1.00	76.57	12.22	39.93974011	49.889	48.39823	48.2399	48.22876	Siri	48.39822795	14936.10331	JO
037	**NW**	16.20	0.70	83.80	10.5	54.4645	61.216	58.806	58.901	.	Siri	1.062	17609.947	JO
037	**NW**	14.30	1.00	85.70	9.3	55.6920	60.950	58.699	58.952	58.791	Siri	1.662	17608.955	JO
037	**NW**	14.80	1.20	85.20	9.6	55.3585	61.010	58.908	58.643	58.705	Siri	1.065	17607.797	JO
037	**NW**	15.1	0.97	84.90	9.81	55.17166703	61.05866667	58.80415	58.83199	58.74812	Siri	1.2629	17608.89968	JO
038	**NW**	28.90	3.20	71.10	19.7	48.3757	65.829	63.729	63.839	.	Siri	1.034	17994.086	JO
038	**NW**	28.10	4.20	71.90	19.1	48.9314	65.736	63.708	63.724	.	Siri	1.035	17995.864	JO
038	**NW**	28.50	3.20	71.50	19.4	48.6444	65.762	63.754	63.761	.	Siri	1.035	17993.550	JO
038	**NW**	28.5	3.53	71.50	19.39	48.6505046	65.77566667	63.73029	63.77465	#DIV/0!	Siri	1.034466667	17994.5002	JO
039	**NW**	32.70	3.00	67.30	19.9	41.0249	59.449	57.708	57.826	.	Siri	1.025	16954.698	JO
039	**NW**	32.40	4.30	67.60	19.8	41.2460	59.460	57.785	57.821	.	Siri	1.026	16961.376	JO
039	**NW**	31.70	4.20	68.30	19.3	41.6702	59.371	57.897	57.646	57.748	Siri	1.028	16960.882	JO
039	**NW**	32.26666667	3.83	67.73	19.68	41.31369942	59.42666667	57.79678	57.7641	57.74847	Siri	1.026366667	16958.98522	JO
041	**OB**	37.90	-1.80	62.10	40.2	65.8982	104.586	101.992	101.925	.	Siri	1.015	22374.915	JO
041	**OB**	37.00	0.40	63.00	39.3	66.8640	104.411	102.032	101.798	.	Siri	1.017	22376.444	JO
041	**OB**	36.40	0.70	63.60	38.6	67.4871	104.271	101.724	101.769	.	Siri	1.018	22374.517	JO
041	**OB**	37.1	-0.23	62.90	39.37	66.74978533	104.4226667	101.9159	101.8306	#DIV/0!	Siri	1.016266667	22375.29232	JO
042	**OB**	33.00	-0.70	67.00	42.5	86.2075	125.544	122.168	122.240	.	Siri	1.025	26132.282	JO
042	**OB**	32.60	-0.50	67.40	41.9	86.7122	125.436	122.299	122.145	.	Siri	1.026	26131.010	JO
042	**OB**	31.20	0.80	68.80	40.1	88.5008	125.043	121.895	122.281	122.194	Siri	1.029	26129.428	JO
042	**OB**	32.26666667	-0.13	67.73	41.51	87.14017667	125.341	122.1205	122.2217	122.1941	Siri	1.0264	26130.9067	JO

Screen Captures of Raw Data from DXA:

ID	GRP	Code	Status	Area (cm2) L arm	Area (cm2) R arm	Area (cm2) L Ribs	Area (cm2) R Ribs	Area (cm2) T Spine	Area (cm2) L Spine	Area (cm2) Pelvis	Area (cm2) L Leg	Area (cm2) R leg	Area (cm2) Subtotal	Area (cm2) Head	Area (cm2) Total
014	OB	DXA	Completed	262.5	265.75	139.97	169.19	143.63	61.26	269.8	428.04	409.37	2149.51	278.32	2427.83
015	OB	DXA	Completed	233.7	235.32	129.83	142.41	138.35	52.74	215.84	372.86	378.94	1899.99	235.32	2135.31
016	NW	DXA	Completed	175.27	182.57	107.11	122.93	127.8	35.3	230.86	357.44	374.48	1713.76	250.33	1964.09
019	OB	DXA	Completed	210.16	205.7	151.33	190.28	144.84	32.05	172.84	348.92	343.24	1799.37	233.7	2033.07
020	NW	DXA	Completed	215.84	218.68	140.38	139.97	133.08	42.19	233.29	392.33	400.45	1916.22	232.07	2148.29
021	NW	DXA	Completed	243.84	246.68	144.84	146.47	143.63	47.88	283.6	403.93	43.88	2091.49	273.86	2365.35
022	NW	DXA	Completed	205.29	205.29	95.75	101.02	121.72	38.54	176.08	327.42	329.45	1600.57	277.92	1878.49
023	NW	DXA	Completed	215.03	202.05	119.69	123.74	127.8	58.83	238.16	389.49	390.3	1865.1	247.49	2112.59
024	OB	DXA	Completed	247.9	268.99	147.28	128.21	146.87	52.74	246.68	409.78	421.95	2070.39	262.5	2332.89
025	OB	DXA	Completed	279.54	296.18	172.03	134.7	154.17	64.1	299.42	498.23	484.43	2382.8	251.55	2634.35
027	NW	DXA	Completed	195.56	214.63	104.68	101.43	127.4	43.41	249.92	377.73	371.64	1786.39	303.48	2089.87
028	NW	DXA	Completed	182.28	202.89	133.78	114.78	115.99	40.01	250.98	349.6	366.98	1757.3	245.73	2003.03
030	OB	DXA	Completed	293.42	311.61	105.08	142.67	145.5	77.19	280.49	512.07	539.56	2407.59	266.34	2673.93
031	NW	DXA	Completed	207.74	221.88	138.22	127.72	134.59	52.14	221.88	356.47	363.75	1824.39	238.86	2063.25
032	NW	DXA	Completed	198.85	186.32	132.16	117.61	139.03	33.14	246.54	361.32	364.15	1779.12	254.22	2033.34
033	NW	DXA	Completed	165.71	167.32	119.63	118.82	120.44	35.16	212.59	328.99	318.88	1587.55	237.65	1825.19
034	NW	DXA	Completed	175.41	183.89	114.38	113.57	115.19	40.42	255.03	335.45	331.01	1664.34	264.73	1929.06
035	OB	DXA	Completed	280.08	301.91	145.09	143.88	136.2	50.92	234.82	458.72	456.7	2208.34	267.15	2475.49
036	NW	DXA	Completed	176.62	185.51	89.32	115.19	118.02	37.18	186.72	278.87	295.85	1483.27	261.49	1744.77
037	NW	DXA	Completed	243.31	263.11	109.12	115.99	121.25	46.88	264.79	368.19	372.64	1905.22	272	2177.22
038	NW	DXA	Completed	231.99	223.91	133.78	115.59	134.18	50.12	217.84	378.3	358.49	1844.19	249.77	2093.96
039	NW	DXA	Completed	178.64	187.13	124.89	130.14	124.48	40.01	187.53	348.98	347.98	1669.19	245.33	1914.51
041	OB	DXA	Completed	247.35	253.41	161.66	152.77	144.29	45.27	217.84	382.34	408.61	2013.53	250.18	2263.71
042	OB	DXA	Completed	302.31	302.31	168.54	120.84	178.24	69.11	246.54	494.29	484.59	2366.77	244.11	2610.89

ID	GRP	BMC (g) L arm	BMC (g) R arm	BMC (g) L Ribs	BMC (g) R Ribs	BMC (g) T Spine	BMC (g) L Spine	BMC (g) Pelvis	BMC (g) L Leg	BMC (g) R leg	BMC (g) Subtotal	BMC (g) Head	BMC (g) Total	BMC M PP (%)	BMC F PP (%)
014	OB	230.89	235.53	86.4	102.97	124.97	63.12	363.17	553.58	531.21	2291.85	622.9	2914.75	107.75	137.23
015	OB	178.87	184.63	78.15	81.03	97.43	47.47	255.89	428.5	447.58	1799.55	459.35	2258.9	83.51	106.35
016	NW	124.78	312.71	58.17	65.96	102.23	35.93	268.61	395.04	409.55	1593.01	505.19	2098.2	76.16	96.38
019	OB	214.99	154.31	81.62	109.45	119.58	27.84	225.27	398.82	382.56	1714.42	445.7	2160.14	79.86	101.70
020	NW	160.89	170.66	85.7	89.3	122.6	50.08	344.17	454.67	462.42	1940.49	601.04	2541.53	93.95674677	119.66
021	NW	206.75	207.95	98.04	97.66	12913	59.84	365.98	508.92	559.28	2233.56	658.14	2891.7	106.9020333	136.14
022	NW	153.21	153.78	50.58	54.56	97.99	35.32	174.82	357.15	357.24	1434.65	530.74	1965.39	275500	90.28
023	NW	163.79	152.67	77.12	76.22	106.26	72.1	324.76	498.59	470.94	1942.44	656.91	2599.35	93.90715318	118.26
024	OB	202.64	223.01	96.62	82.96	141.41	52.72	362.46	506.4	512.28	2180.51	568.3	2748.8	101.6192237	129.42
025	OB	257.35	275.65	131.29	100.37	152.47	81.33	442.45	659.37	596.7	2696.98	658.48	3355.46	124.0465804	157.98
027	NW	147.22	156.42	68.03	57.64	108.9	45.78	293.37	388.94	386.5	1652.79	669.7	2322.49	85.85914972	109.35
028	NW	121.55	143.47	79.19	60.21	83.14	37.52	265.59	367.78	368.65	1527.11	512.43	2039.54	75.39889094	96.02
030	OB	289.38	316.21	86.67	110.22	187.42	94.31	470.05	749.57	764.87	3068.71	655.46	3724.17	136.2168983	173.06
031	NW	151.85	166.23	91.53	80.26	113.79	53.85	281.11	399.47	410.36	1748.43	580.04	2328.47	275500	106.96
032	NW	152.54	138.89	87.64	78.58	130.11	39.97	355.89	440.93	443.21	1867.77	612.56	2480.32	91.69390018	116.78
033	NW	126.68	131.97	68.8	65.87	106.02	41.1	295.37	370.47	371.05	1577.33	457.55	2034.89	75.22698706	95.80
034	NW	123.42	133.2	65.15	64.83	100.71	41.42	277.62	387.42	374.25	1568.02	647.99	2216.01	81.92273567	104.33
035	OB	239.74	261.74	101.12	95.81	122.18	45.93	287.88	519.23	516.27	2189.91	583.95	2773.86	101.4579371	128.90
036	NW	133.81	148.71	53.89	66.58	102.24	41.19	217.96	284.8	313.01	1362.19	555.97	133.81	4.94676525	6.30
037	NW	209.44	225.73	76.85	70.68	108.2	50.35	315.76	453.69	460.6	1971.31	641.99	2613.3	96.60998152	123.04
038	NW	157.19	154.48	81.73	67.54	90.91	46.59	226.63	374.38	344.42	1543.88	494.95	2038.83	75.37264325	95.99
039	NW	130.65	135.75	70.12	68.28	100.5	40.13	231.8	390.13	383.42	1550.77	556.9	2107	77.89279113	99.20
041	OB	211.74	224.18	104.6	95.7	127.08	49.2	297.59	427.9	2010.93	538.6	2549.53	2549.53	94.25249538	120.03
042	OB	279.08	279.08	113.42	72.09	149.67	67.46	360.39	751.81	660.35	2733.34	460.35	3193.69	116.8138259	148.41

ID	GRP	BMD (g/cm2) L arm	BMD (g/cm2) R arm	BMD (g/cm2) L Ribs	BMD (g/cm2) R Ribs	BMD (g/cm2) T Spine	BMD (g/cm2) L Spine	BMD (g/cm2) Pelvis	BMD (g/cm2) L Leg	BMD (g/cm2) R leg	BMD (g/cm2) Subtotal	BMD (g/cm2) Head	BMD (g/cm2) Total	BMD M PP (%)	BMD F PP (%)
014	OB	0.88	0.886	0.617	0.609	0.87	1.03	1.346	1.293	1.298	1.066	2.238	1.201	101.350211	109.7806216
015	OB	0.765	0.785	0.602	0.569	0.704	0.9	1.186	1.149	1.181	0.947	1.952	1.058	89.28270042	96.70932358
016	NW	0.712	0.727	0.543	0.537	0.8	1.018	1.164	1.104	1.094	0.93	2.018	1.068	88.85191348	95.78475336
019	OB	1.023	0.75	0.539	0.575	0.826	0.869	1.303	1.143	1.115	0.953	1.907	1.063	89.70464135	97.16636197
020	NW	0.745	0.78	0.611	0.638	0.921	1.187	1.475	1.159	1.155	1.013	2.59	1.183	99.83122363	108.1352834
021	NW	0.848	0.843	0.677	0.667	0.667	0.899	1.25	1.29	1.261	1.298	1.068	1.223	103.2067511	111.7915905
022	NW	0.746	0.749	0.528	0.54	0.805	0.916	0.993	1.091	1.084	0.896	1.91	1.046	87.02163062	93.81165919
023	NW	0.762	0.756	0.644	0.616	0.831	1.225	1.364	1.28	1.207	1.041	2.654	1.23	102.6711185	109.6256684
024	OB	0.817	0.829	0.656	0.647	0.963	1	1.469	1.236	1.214	1.053	2.165	1.178	99.4092827	107.678245
025	OB	0.921	0.931	0.763	0.745	0.989	1.269	1.478	1.323	1.232	1.132	2.618	1.274	107.5105485	116.4533821
027	NW	0.753	0.729	0.65	0.568	0.855	1.055	1.174	1.03	1.04	0.925	2.207	1.111	93.75527426	101.5539305
028	NW	0.667	0.707	0.592	0.525	0.717	0.938	1.058	1.052	1.005	0.869	2.085	1.018	85.907173	93.05301645
030	OB	0.986	1.015	0.825	0.773	1.288	1.222	1.676	1.464	1.418	1.275	2.461	1.393	116.4715719	125.9493671
031	NW	0.731	0.749	0.662	0.628	0.845	1.033	1.267	1.121	1.128	0.958	2.428	1.129	93.92678869	101.2556054
032	NW	0.767	0.745	0.663	0.668	0.936	1.206	1.444	1.22	1.217	1.05	2.41	1.22	102.9535865	111.5173675
033	NW	0.764	0.789	0.575	0.554	0.88	1.169	1.389	1.126	1.164	0.994	1.925	1.115	94.092827	101.9195612
034	NW	0.704	0.724	0.57	0.571	0.874	1.025	1.089	1.155	1.131	0.942	2.448	1.149	96.96202532	105.0274223
035	OB	0.856	0.867	0.697	0.666	0.897	0.902	1.226	1.132	1.13	0.992	2.186	1.121	93.72909699	101.3562387
036	NW	0.758	0.802	0.603	0.578	0.866	1.108	1.167	1.021	1.058	0.918	2.126	1.099	92.74261603	100.4570384
037	NW	0.861	0.858	0.704	0.609	0.892	1.074	1.193	1.232	1.236	1.035	2.36	1.2	101.2658228	109.6892139
038	NW	0.678	0.69	0.611	0.584	0.677	0.93	1.04	0.99	0.961	0.837	1.982	0.974	82.19409283	89.03107861
039	NW	0.731	0.725	0.561	0.525	0.807	1.003	1.236	1.12	1.102	0.929	2.27	1.101	92.91139241	100.6398537
041	OB	0.856	0.885	0.647	0.626	0.881	1.087	1.366	1.119	1.157	0.999	2.153	1.126	95.02109705	102.9250457
042	OB	0.923	0.923	0.673	0.597	0.84	0.976	1.462	1.521	1.363	1.155	1.866	1.223	102.2575251	110.5786618

ID	GRP	Fat Mass (g) L Arm	Fat Mass (g) R Arm	Fat Mass (g) Trunk	Fat Mass (g) L Leg	Fat Mass (g) R Leg	Fat Mass (g) Subtotal	Fat Mass (g) Head	Fat Mass (g) Total	Fat Mass (g) Android	Fat Mass (g) Gynoid
014	OB	1728	1728	12572	4347	4266	24640	1704	26344	2116	4239
015	OB	1896	2016	14093	5648	5806	29459	1300	30759	2659	5609
016	NW	708	674	4176	3025	3362	11944	1124	13069	615	3026
019	OB	1883	1955	18407	4692	4644	31581	1456	33037	2932	4988
020	NW	1337	1300	7460	3998	4409	18503	1138	19641	1172	3971
021	NW	854	864	6868	2702	2909	14197	1307	15504	1208	3115
022	NW	904	846	4465	2605	2736	11557	1372	12929	665	2212
023	NW	1473	1365	9920	4786	5070	22614	1149	23764	1573	4786
024	OB	1685	1682	12508	4340	4393	24608	1473	26081	2148	4575
025	OB	2198	2295	15810	6363	6492	33157	1569	34756	2930	5919
027	NW	1052	1028	6424	3743	3981	16228	1473	17701	1122	3961
028	NW	796	864	4258	2825	2797	11540	1143	12684	679	3072
030	OB	2334	2362	16524	5418	5235	31874	1771	33644	3105	5155
031	NW	1267	1295	11892	4533	4654	23642	1074	24716	2112	5083
032	NW	936	842	5970	2815	3035	13598	1169	14767	842	2958
033	NW	878	897	6708	2699	2859	14041	1047	15087	1014	2854
034	NW	795	733	4044	3025	2121	11718	1213	12931	636	2974
035	OB	1759	1786	13107	5009	5397	27057	1453	28510	2378	4543
036	NW	814	901	4358	2877	2835	11784	1159	12943	780	2728
037	NW	787	937	4570	2366	2625	11285	1297	12582	781	2380
038	NW	1697	1696	8323	4737	4621	21074	1187	22261	1218	4341
039	NW	1209	1164	9086	3223	3413	18096	1225	19320	1283	3157
041	OB	2336	2528	187778	6035	6337	36014	1891	37905	3170	5607
042	OB	3075	3075	19934	7166	7246	40496	1430	41926	3854	6698

ID	GRP	Lean+ BMC (g) L Arm	Lean+ BMC (g) R Arm	Lean+ BMC (g) Trunk	Lean+ BMC (g) L Leg	Lean+ BMC (g) R Leg	Lean+ BMC (g) Subtot	Lean+ BMC (g) Head	Lean+ BMC (g) Total	Lean+ BMC (g) Androi	Lean+ BMC (g) Gynoi
014	OB	4733	4921	33561	11146	10887	65247	5163	70410	4143	9885
015	OB	37.61	38.7	30441	10635	10515	59222	3886	63108	4202	10387
016	NW	1921	2057	20250	6780	6852	37860	3489	54418	3349	9157
019	OB	3592	3840	29674	9814	10489	57410	4164	61573	4127	9956
020	NW	2267	2439	23031	7959	8532	44228	3586	47814	2914	7366
021	NW	3384	3362	25464	9336	9870	51417	4117	55535	3134	8433
022	NW	2916	2970	22125	7362	7527	42901	4207	47108	2679	6366
023	NW	2224	2337	22202	7809	7902	42473	3646	46119	2964	7221
024	OB	3895	4419	32908	10552	11307	63081	4449	67530	4798	9852
025	OB	4594	5251	36358	14030	13697	73931	4791	78722	5619	12262
027	NW	2831	2951	25271	9662	9502	50217	4592	54808	3165	8177
028	NW	1996	2437	22063	7404	7396	41296	3553	44849	3038	6954
030	OB	5964	6366	38369	13493	14136	78328	5268	83597	5146	11096
031	NW	2254	2500	23746	7071	7409	42980	3397	46377	3131	7282
032	NW	2793	2631	24221	8985	9140	47770	3688	51458	3058	8355
033	NW	2193	2401	18653	6423	6597	36266	3241	39507	2153	5943
034	NW	2283	2516	19748	7328	7598	39472	3839	43311	2591	6928
035	OB	5228	5537	34041	11279	11053	67138	4461	71600	4629	9845
036	NW	2268	2502	18210	6383	6975	36338	3648	39986	2174	5339
037	NW	3761	4039	24602	8197	8982	49581	4135	53716	3359	8129
038	NW	2256	2381	23019	7381	7424	42460	3644	46104	3015	7346
039	NW	2096	2342	20497	6974	6937	38846	3786	42633	2510	6033
041	OB	4720	5199	32254	10571	11487	65230	5270	69501	4446	10284
042	OB	5898	5898	43498	15269	14513	85076	4128	89204	7089	13721

ID	GRP	Total Mass (g) L Arm	Total Mass (g) R Arm	Total Mass (g) Trunk	Total Mass (g) L Leg	Total Mass (g) R Leg	Total Mass (g) Subtot	Total Mass (g) Head	Total Mass (g) Total	Total Mass (g) Androi	Total Mass (g) Gynoi
014	OB	6460	6659	46132	15493	15154	89888	6867	96754	6259	14124
015	OB	5656	5886	44534	16283	34.7	88681	5185	93866	6861	15996
016	NW	2629	2731	24426	9804	10214	49805	4613	54418	0.3349	9157
019	OB	5476	5795	48080	14506	15134	88991	5620	94610	7059	14944
020	NW	3605	3739	30490	11957	12940	62731	4724	67455	4086	11337
021	NW	4239	4226	32333	12039	12788	65614	5424	71039	4342	11549
022	NW	3820	3816	26590	9967	10263	54457	5580	60037	3345	8578
023	NW	3697	3702	32121	12595	12972	65087	4796	69883	4537	12008
024	OB	5580	6101	45416	14891	15700	87689	5921	93611	6946	14428
025	OB	6792	7546	52168	20392	20189	107087	6360	113448	8548	18181
027	NW	3883	3979	31695	13404	13483	66444	6065	72509	4287	12138
028	NW	2793	3301	26320	10229	10193	52836	4697	57532	3716	10026
030	OB	8298	8729	54894	18911	19371	110202	7039	117241	8251	16250
031	NW	3521	3795	35637	11604	12064	66622	4471	71092	5244	12365
032	NW	3729	3473	30192	11800	12174	61368	4858	66226	3900	11313
033	NW	3070	3298	25361	9121	9457	50307	4287	54594	3167	8797
034	NW	3078	3248	23791	10353	10718	51190	5052	56241	3227	9902
035	OB	6987	7323	47148	16287	16450	94195	5914	100110	706	14388
036	NW	3081	3403	22567	9260	9810	48122	4807	52929	2953	8067
037	NW	4548	4976	29172	10563	11607	60866	5432	66298	4140	10510
038	NW	3952	4077	31342	12118	12045	63534	4830	68364	4234	11687
039	NW	3305	3506	29583	101998	10350	56942	5011	61953	3794	9190
041	OB	7057	7727	51032	16606	17824	100245	7161	107405	7616	15891
042	OB	8973	8973	63432	22435	21759	125572	5558	131129	10943	20419

ID	GRP	% Fat L Arm	% Fat R Arm	% Fat Trunk	% Fat L Leg	% Fat R Leg	% Fat Subtotal	% Fat Head	% Fat Total	% Fat M PP	% Fat F PP
014	OB	26.7	26	27.3	28.1	28.2	27.4	24.8	27.2	116.24	77.49
015	OB	33.5	34.3	31.6	34.7	35.6	33.2	25.1	32.8	140.17	93.45
016	NW	26.9	24.7	17.1	30.9	32.9	24	24.4	24	93.39	64.86
019	OB	34.4	33.7	383	32.3	30.7	35.5	25.9	34.9	149.15	99.43
020	NW	37.1	34.8	24.5	33.4	34.1	29.5	24.1	29.1	124.36	82.91
021	NW	20.2	20.4	21.2	22.4	2.8	21.6	24.1	21.8	93.16	62.11
022	NW	23.7	22.2	16.8	26.1	26.7	21.2	24.6	21.5	83.66	58.11
023	NW	39.9	36.9	30.9	38	39.1	34.7	24	34	123.64	87.40
024	OB	30.2	27.6	27.5	29.1	28	28.1	24.9	27.9	119.23	79.49
025	OB	32.4	30.4	30.3	31.2	32.2	31	24.7	30.6	130.77	87.18
027	NW	27.1	25.8	20.3	27.9	29.5	24.4	24.3	24.4	104.27	69.52
028	NW	28.5	26.2	16.2	27.6	27.4	21.8	24.3	22	94.02	62.68
030	OB	28.1	27.1	30.1	28.7	27	28.9	25.2	28.7	116.67	79.72
031	NW	36	34.1	33.4	39.1	38.6	35.5	24	34.8	135.41	94.05
032	NW	25.1	24.2	19.8	23.9	24.9	22.2	24.1	22.3	95.30	63.53
033	NW	28.6	27.2	26.5	29.6	30.2	27.9	24.4	27.6	117.95	78.63
034	NW	25.8	22.6	17	29.2	29.1	22.9	24	23	98.29	65.53
035	OB	25.2	24.4	27.8	30.8	32.8	28.7	24.6	28.5	115.85	79.17
036	NW	26.4	26.5	19.3	31.1	28.9	24.5	24.1	24.5	104.70	69.80
037	NW	17.3	18.8	15.7	22.4	22.6	18.5	23.9	19	81.20	54.13
038	NW	42.9	41.6	26.6	39.1	38.4	33.2	24.6	32.6	139.32	92.88
039	NW	36.6	33.2	30.7	31.6	33	31.8	24.4	31.2	133.33	88.89
041	OB	33.1	32.7	36.8	36.3	35.6	35.9	26.4	35.3	150.85	100.57
042	OB	34.3	34.3	31.4	31.9	33.3	32.2	25.7	32	130.08	88.89

ID	GRP	% Fat Android	% Fat Gynoid	Fat Mass/Height 2 (kg/m2)	Fat Mass/Height 2 M PP	Fat Mass/Height 2 F PP	Android/Gynoid Ratio	%Fat Trunk/%Fat Legs	%Fat Trunk/%Fat Legs M Pl	%Fat Trunk/%Fat Legs F Pl	Trunk/Limb Fat Mass Ratio	Trunk/Limb Fat Mass Ratio M Pl	Trunk/Limb Fat Mass Ratio F Pl
014	OB	33.8	30	8.41	141.34	99.17	1.13	0.97	109.85	127.80	1.04	112.31	139.60
015	OB	38.8	35.1	10.3	173.11	121.46	1.11	0.9	101.93	118.58	0.92	99.35	123.49
016	NW	18.4	33	4.55	67.11	48.66	0.56	1	102.15	123.46	0.54	50.80	64.21
019	OB	41.5	33	12.7	213.45	149.76	1.24	1.22	138.17	160.74	1.4	151.19	187.92
020	NW	28.7	35	6.7	112.61	79.01	0.82	0.72	81.54	94.86	0.68	73.43	91.28
021	NW	27.8	27	5.06	85.04	59.67	1.03	0.94	106.46	123.85	0.94	101.51	126.17
022	NW	19.9	25.8	4.83	71.24	51.66	0.77	0.64	65.37	79.01	0.63	59.27	74.91
023	NW	34.7	39.9	8.48	112.02	82.57	0.87	0.8	75.76	94.34	0.78	65.93	86.96
024	OB	30.9	31.7	8.67	145.71	102.24	0.98	0.96	108.72	126.48	1.03	111.23	138.26
025	OB	34.3	32.6	10.4	174.79	122.64	1.05	0.96	108.72	126.48	0.91	98.27	122.15
027	NW	26.2	32.6	5.95	100.00	70.17	0.8	0.71	80.41	93.54	0.66	71.27	88.59
028	NW	18.3	30.6	4.58	76.97	54.01	0.6	0.59	66.82	77.73	0.58	62.63	77.85
030	OB	37.6	37.7	9.17	143.96	103.03	1.19	1.08	115.76	137.40	1.08	108.54	135.68
031	NW	40.3	41.1	8.79	0.98	0.86	1.01	0.86	87.84	106.17	1.01	95.01	120.10
032	NW	21.6	26.1	5.34	89.75	62.97	0.83	0.81	91.73	106.72	0.78	84.23	104.70
033	NW	32	32.4	5.76	96.81	67.92	0.99	0.88	99.66	115.94	0.91	98.27	122.15
034	NW	19.7	30	4.8	80.67	56.60	0.66	0.58	65.69	76.42	0.53	57.24	71.14
035	OB	33.9	31.6	8.69	136.42	97.64	1.07	0.87	93.25	110.69	0.94	94.47	118.09
036	NW	26.4	33.8	5.39	90.59	63.56	0.78	0.64	72.48	84.32	0.59	63.71	79.19
037	NW	18.9	22.6	4.25	71.43	50.12	0.83	0.7	79.28	92.23	0.68	73.43	91.28
038	NW	28.8	37.1	7.57	127.23	89.27	0.77	0.69	78.14	90.91	0.65	70.19	87.25
039	NW	33.8	34.4	6.81	114.45	80.31	0.98	0.95	107.59	125.16	1.01	109.07	135.57
041	OB	41.6	35.3	11.9	200.00	140.33	1.18	1.02	115.52	134.39	1.09	117.71	146.31
042	OB	35.2	32.8	10.7	167.97	120.22	1.07	0.96	102.89	122.14	0.97	97.49	121.86

ID	GRP	Est. VAT Mass (g)	Est. VAT Volume (cm3)	Est. VAT Area (cm2	Lean/Height2 (kg/m2)	Lean/Height2 (kg/m2) M I	Lean/Height2 (kg/m2) F F	Appen. Lean/Height2 (kg/m2)	Appen. Lean/Height2 (kg/m2) M I	Appen. Lean/Height2 (kg/m2) F F
014	OB	515	557	107	21.5	113.28	137.82	9.61	108.34	141.12
015	OB	553	598	115	20.4	107.48	130.77	9.23	104.06	135.54
016	NW	218	236	45.3	13.7	69.90	85.46	5.77	63.97	83.62
019	OB	491	531	102	22.9	120.65	146.79	10.3	116.12	151.25
020	NW	199	216	41.4	15.4	81.14	98.72	6.81	76.78	100.00
021	NW	275	297	57	17.2	90.62	110.26	7.99	90.08	117.33
022	NW	226	244	46.8	16.9	86.22	105.43	7.38	81.82	106.96
023	NW	290	314	60.2	15.5	77.35	95.09	6.78	74.34	97.55
024	OB	373	403	77.4	21.5	113.28	137.82	9.55	107.67	140.23
025	OB	492	531	102	22.5	118.55	144.23	10.7	120.63	157.12
027	NW	206	222	42.7	17.6	92.73	112.82	8.02	90.42	117.77
028	NW	189	205	39.3	15.5	81.66	99.36	6.59	74.30	96.77
030	OB	486	525	101	21.8	112.89	137.71	10.3	115.21	150.15
031	NW	402	435	83.5	15.7	80.10	97.94	6.44	71.40	93.33
032	NW	173	187	35.8	17.7	93.26	113.46	8.08	91.09	118.65
033	NW	187	202	38.7	14.3	75.34	91.67	6.35	71.59	93.25
034	NW	162	175	33.7	15.3	80.61	98.08	6.95	78.35	102.06
035	OB	333	359	69	21	108.75	132.66	9.62	107.61	140.23
036	NW	132	143	27.4	15.9	83.77	101.92	7.18	80.95	105.43
037	NW	316	341	65.5	17.3	91.15	110.90	7.99	90.08	117.33
038	NW	262	283	54.4	15	79.03	96.15	6.26	70.57	91.92
039	NW	289	313	60	14.3	75.34	91.67	6.1	68.77	89.57
041	OB	694	751	144	21	110.64	134.62	9.61	108.34	141.12
042	OB	657	710	136	22	113.93	138.98	10.1	112.98	147.23

Appendix B

Institutional Review Board Approval:

Appalachian STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD
Office of Research Protections
ASU Box 32068
Boone, NC 28608
828.262.2692
Web site: http://researchprotections.appstate.edu
Email: irb@appstate.edu
Federalwide Assurance (FWA) #00001076

To: Jayvaughn Oliver
Health and Exercise Science
CAMPUS EMAIL

From: Dr. Andrew Shanely, IRB Chairperson
RE: Notice of IRB Approval by Full Board Review
Agrants #:
Grant Title:

STUDY #: 18-0355
STUDY TITLE: Body composition using air displacement plethysmography in obese adults: effect of estimated versus measured thoracic gas volume
Submission Type: Initial
Approval Date: 2/23/2019
Expiration Date of Approval: 2/22/2020

The Institutional Review Board (IRB) reviewed this study at a convened meeting and approved this study for the period indicated above. IRB approval is limited to the activities described in the IRB approved materials, and extends to the performance of the described activities in the sites identified in the IRB application. In accordance with this approval, IRB findings and approval conditions for the conduct of this research are listed below.

Study Regulatory and other findings:

The IRB determined that this study involves more than minimal risk to participants.

All approved documents for this study, including consent forms, can be accessed by logging into IRBIS. Use the following directions to access approved study documents.

1. Log into IRBIS
2. Click "Home" on the top toolbar
3. Click "My Studies" under the heading "All My Studies"
4. Click on the IRB number for the study you wish to access
5. Click on the reference ID for your submission
6. Click "Attachments" on the left-hand side toolbar
7. Click on the appropriate documents you wish to download

Appendix C

Informed Consent Statement Form:

Appalachian State University
Informed Consent for Participants in
Research Projects Involving Human Subjects

Title of Project:	**Estimation of body composition via air displacement plethysmography using measured and predicted thoracic gas volumes in normal weight and obese adults**
IRB Study #:	**18-0355**

Principal Investigator:	Jonathon Stickford, Ph.D.	Email: stickfordjl@appstate.edu
Research Assistants:	Jayvaughn Oliver, B.S.	Email: oliverjt@appstate.edu
	Erica Larson, M.S.	Email: larsone@appstate.edu
	Dalton Fletcher, B.S.	Email: fletcherds@appstate.edu
	John Cantu, B.S.	Email: cantujw@appstate.edu

This is to certify that I, ____ have been given the following information with respect to my participation as a volunteer in a program of investigation under the supervision of Jonathon Stickford, Ph.D. to which Jayvaughn Oliver, B.S., Erica Larson, M.S, Dalton Fletcher B.S., and John Cantu may be assisting.

1. **Purpose of the study:**

   Obesity has become a large issue in the US. Obesity-related conditions are the second leading cause of preventable death. Understanding more about obesity is important for the effective treatment of over 78 million people in the US.

   The main objective of this study is to investigate the measurement of body fat in an obese population using measured versus predicted values of lung volumes in the Bod Pod. The measurements will be compared to values of body fat using DXA. The results from this study could provide further insight on how these measures may agree in an obese population.

2. **Inclusion Criteria: You may participate in the study if the following apply to you:**

   - Age: 18 – 45 years of age. The reason for the upper cut-off being that older adults are more likely to present with physical differences that could affect the outcomes of some measurements.

- BMI between 18.5 and 24.9, or between 30 and 40.
- Must be a non-smoker or smoked less than half a pack of cigarettes a day over the course of a year.
- Have no known lung, heart, kidney disease or energy limitations, or exhibit any signs or symptoms of lung, heart, and kidney disease or energy limitations.
- Interested in participating in the research study.
- Understand written and oral instructions in English.
- Provide informed consent.
- Available during times the data collection are offered.

Exclusion Criteria: You should not participate in this study if any of the following apply to you:

- BMI between 25 and 29.9.
- Current smoker or previously smoked more than half a pack of cigarettes a day over the course of a year
- Known lung, heart, kidney disease or energy limitation, or signs/symptoms suggestive of known lung, heart, kidney disease or energy limitation will exclude you from participation.
- Pregnant
- Unable to understand written and oral instructions in English.

3. **Procedures:** ***Please read the descriptions of each step in the experiment and write your initials in the space provided.***

    You could be asked to repeat a trial, procedure, or test. This could happen for many reasons such as equipment failure, power outage, inconclusive test results, etc. However, you do not have to repeat a trial, procedure, and/or test if you do not wish to do so.

Below is a timeline showing all visits and experiments which you will complete in this study.

Pre-Screen	**Visit 1**
Screening Question (~10 minutes) →	Informed Consent & Questionnaires (~40 minutes) Bod Pod (~15 minutes) DXA (~15 minutes)

…

________ **initial** **Prescreen:** You may be telephoned by the Principle Investigator or a Research Assistant (see page 1) and asked screening questions to determine your eligibility for the study (~10 minutes).

Visit 1:

________ **Initial** **Consent and Questionnaires:** Potential participants who meet inclusion criteria will be invited to a screening interview within the laboratory located off campus (Levine Hall). At this screening visit, the study will be explained in detail to you by the PI or a trained research assistant. You will have time to consider your options and get all questions answered - if you agree to participate, you will then provide your written informed consent.

After you have provided consent (~15 minutes), you will be asked to complete questionnaires: 1) a medical history questionnaire (~15 minutes), and 2) a 24 hour health history questionnaire (~10 minutes).

________ **initial** **Bod Pod:** After completing the questionnaires, we will measure your height, weight, and body composition. Your percent body fat will be measured using the Bod Pod. You will sit in a chamber and may hear some clicking while air pressure changes to measure your body volume. This piece of equipment estimates your body's composition of fat and fat free mass by air movement. This is accomplished by measuring your mass and body volume which is then us to calculate fat mass and fat free mass. This is an extremely accurate method and presents no risk. These procedures will take ~15 minutes total.

________ **initial** **DXA:** A DXA is a type of X-ray used to measure bone strength. During this test, X-ray pictures of your body will measure how much fat and muscle are present. You will lie flat on a table and a machine will take pictures of different areas of the body. This test will last about 15 minutes.

3. Discomforts and risks:

There are minimal risks involved with measuring/monitoring/performing: questionnaires, physical characteristics, and body composition.

DXA: The risks associated with a DXA scan include exposure to small amounts of radiation. DXA scanning uses radiation to obtain an image of your body. Everyone receives a small amount of unavoidable radiation from the environment each year. Some of this radiation comes from space and some from naturally-occurring forms of radioactive water and minerals. The DXA scan technique gives your body the equivalent of about 4 extra days' worth of this natural radiation. The radiation dose we have discussed is what you will receive from this study only and does not include any exposure you may have received or will receive from other tests. If you are pregnant or trying to get pregnant, you should not participate in a DXA scan

Loss of Confidentiality: Any time information is collected; there is a potential risk for loss of confidentiality. Every effort will be made to keep your information confidential; however, this cannot be guaranteed.

Other Risks: There may possibly be other side effects that are unknown at this time. If you are concerned about other, unknown side effects, please discuss this with the researchers.

How you can help reduce some of the risks: During your participation in this research, the researchers will closely observe your testing to determine whether there are problems that need medical care. It is your responsibility to do the following:

- Ask questions about anything you do not understand.
- Keep appointments.
- Follow the study researchers' instructions.
- Let the researchers know if your telephone number changes.
- Tell the researchers before you take any new medication.
- Tell your regular doctor about your participation in this research.
- Talk to a family member or friend about your participation in this research.

4. a. Benefits to me: You will receive a copy of your body composition. These screenings are being performed only for research purposes and are not to be understood as a clinical screening intended for diagnostic or therapeutic purposes. The screening data will not be read for any health care or diagnostic purpose. Under no circumstance will the investigator, research staff or other University employee interpret your screening as normal or abnormal and they are unable to make any medical comments or interpretations based on your results. Please contact your health care provider if you have any questions regarding this data.

b. Potential benefits to society: The results of this study could alter the standard protocols used to measure body fat % using a Bod Pod.

5. Alternative procedures that could be utilized: Not participating in the study. The procedures used in this study are frequently used in research and are the most appropriate methods to accomplish the goals of this research.

6. Time duration of the procedures and study:

________ initial Pre-screening (about 10-15 min).

You will need to visit the laboratory for the following:

________ initial Visit 1 (about 1.5 hours).

Approximately 2 hours Total

7. Statement of confidentiality: Volunteers are coded by an identification number for statistical analyses. All records are kept in a secure location. All records associated with your participation in the study will be subject to the university confidentiality standards and in the event of any publication resulting from the research no personally identifiable information will be disclosed. The Office of Human Research Protections in the U.S. Department of Health and Human Services, the Office for Research Protections at

Appalachian State University and the Institutional Review Board may review records related to this project.

8. **Right to ask questions:** Please contact Jonathon Stickford, Ph.D. (828-262-7471), with questions, complaints, or concerns about this research. If you have any questions about your rights as a research subject, please contact the IRB Administrator at the Appalachian State University Institutional Review Board Office at (828) 262-2692, irb@appstate.edu. This study has been approved on February 23, 2019 by the Institutional Review Board (IRB) at Appalachian State University. This approval will expire on February 22, 2020 unless the IRB renews the approval of this research.

9. **Injury Clause:** In the unlikely event you become injured as a result of your participation in this study, standard emergency procedures will be followed. If you get hurt or sick when you are not at the research site, you should call your doctor or call 911 in an emergency. If your illness or injury could be related to the research, tell the doctors or emergency room staff about the research study, the name of the Principal Investigator, and provide a copy of this consent form if possible. Please call the PI as soon as possible (Jonathon Stickford, Ph.D. 828-262-7471). It is the policy of this institution to provide neither financial compensation nor free medical treatment for research-related injury. You will be responsible for any costs for medical care not paid by your insurance company. No other compensation is offered by Appalachian State University. By signing this document, you are not waiving any legal rights that you have against Appalachian State University for injury resulting from negligence of the University or its investigators.

10. **Voluntary participation:** Your participation in this study is voluntary. You may withdraw from this study at any time by informing the research personnel. You may decline to answer certain questions and may decide not to comply with certain procedures. However, your being in the study may be contingent upon answering these questions or complying with the procedures. The researcher may end your role in the study without your consent if the researcher deems that your health or behavior adversely affects the study or increases risks to you beyond those approved by the Institutional Review Board and agreed upon by you in this document. You have been given an opportunity to ask any questions you may have, and all such questions or inquiries have been answered to your satisfaction.

You must be 18 years of age or older to take part in this research study. If you agree to take part in this research study and have read the information outlined above, please sign your name and indicate the date below. You will be given a copy of this signed and dated consent form for your records.

____

Volunteer Date

I, the undersigned, have defined and explained the studies involved to the above volunteer.

Person Obtaining Consent Date

Appendix D

Telephone Screening Form:

Initial Telephone Screening Form for Study
VTG

VTG

We are conducting a study to examine the effect of lung volumes on measurements of body composition. We will do a series of measurements using the Bod Pod and DXA where we will analyze resultant measures of body composition. Effort for each of these tasks will be minimal. This screening is meant to determine if you are eligible to participate in the study. Basic demographic information will be asked along with a brief health history. If you choose not to participate, or do not qualify for the study, all of this information will be shredded. Are you interested in about learning more and potentially participating in this study?

Great! Well to begin I would like to ask you some general Information:

What is your name, age, and year or birth?

What Gender do you identify as?

May I have your contact information to reach you when necessary, like your email and phone number?

To the best of your knowledge what is your height and weight?

Do you have any allergies to latex?

Do you currently smoke tobacco or electronic cigarettes?

Have you ever been diagnosed with a sleep disorder or use CPAP?

Do you have a history of asthma, COPD, or any lung issues?

Do you have a history of an irregular heartbeat or any heart condition? (Have you had an EKG performed?)

Do you have any known health conditions?

High blood pressure?
Diabetes?
Thyroid issues?

Are you pregnant?

Thank you for taking the time to complete this screening questionnaire.

Based on the information that you have provided we would like to invite you to the lab to potentially participate in this study. Upon arrival, you will be provide with further details of the study, and provided your consent we will continue to move forward. Thank you for your time.

Based on the information you have provided, you do not qualify for this study. I am sorry about this, but I encourage you to continue pursuing research. Thank you for your time and have a great day.

Appendix E

Medical History Form:

Appalachian State University – Integrative Human Physiology Laboratories

251 Industrial Park Dr. Boone, NC 28607 Phone: (828)262-7471

ASU **Medical History Form** **Page 1**

Subject ID#: **Study:**

Highest Education Achieved:

Ethnicity:

☐ ***Hispanic or Latino.*** A person of Cuban, Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race. The term "Spanish origin" can be used in addition to "Hispanic or Latino."

☐ ***Not Hispanic or Latino.***

Race: What race do you consider yourself to be?

☐ ***American Indian or Alaska Native***. A person having origins in any of the original peoples of North, South, or Central America, and who maintains a tribal affiliation or community attachment.

☐ ***Asian.*** A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent, including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam. (Note: Individuals from the Phillippine Islands have been recorded as Pacific Islanders in previous data collection strategies.)

☐ ***Black or African American***. A person having origins in any of the black racial groups of Africa. Terms such as "Haitian" or "Negro" can be used in addition to "Black" or "African American".

☐ ***Native Hawaiian or Pacific Islander***. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific islands.

☐ ***White.*** A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

☐ ***Check here if you do not wish to disclose any or all of the above information.***

Medications: include over the counter drugs/oral contraceptives/dietary supplements

Name/Dosage/How often taken:

Allergies:

Smoking History:

Do you smoke? Yes No Cigarettes? Pipe / Cigar? Other? If you quit, what year did you quit ______

______# packs per day for_________# of years What year did you start smoking? _________

Have you ever been exposed to second hand smoke?______Home______Work_____Other_____Years

Alcohol Consumption History:

Do you currently drink alcohol? If you drank alcohol previously, when did you stop?

If you ever did drink alcohol, what is (was) the volume consumed?
_______# ounces / day for_________# of years

ASU	Medical History Form	Page 2

Medical History:

NO	YES	Please explain any "YES" answers below:
		high blood pressure
		swelling
		chest pain / history of heart attack
		extra heart beats, racing or fluttering
		abnormal electrocardiogram (ECG)
		other heart trouble (e.g. murmur, valve problems)
		high cholesterol
		diabetes (e.g. frequent urination and abnormal thirst)
		seizures
		stroke
		fainting or black-out spells, dizziness
		anxiety (diagnosed)
		depression (diagnosed)
		recurrent fatigue (e.g. feeling tired or extreme lack of energy)
		insomnia or poor sleeping
		thyroid problems
		difficulty breathing
		emphysema/ asthma/ chronic bronchitis
		cough, sputum (phlegm)
		tuberculosis
		chronic infection
		stomach/GI problems (e.g. heart burn, nausea, vomiting, diarrhea, constipation, abdominal pain, gas pain, black stools, blood in stools)
		hepatitis
		bleeding disorder (e.g. bleeding or bruising easily)
		kidney/ urinary problems (e.g. frequent urination, burning when urinating, urine changing in color)
		joint injuries/ joint pain, back pain, or leg pain
		arthritis (rheumatoid or osteoarthritis)
		hearing problems (e.g. impaired hearing or ringing in the ears)
		migraine headaches
		vision problems (exclude corrected near/far sightedness)
		surgical procedures (e.g. c-sections, appendectomy, augmentations, knee and back surgeries, tonscillectomy, etc)

Additional Notes:

ASU	Medical History Form	Page 3

Exercise History:		
Do you currently exercise aerobically?	How many years?	Duration:
	Types of Exercise:	Frequency:
Do you compete in endurance events?	How many years?	Frequency:
	What events?	Athlete in college? Yes No
Any other types of exercise?	How many years?	Duration:
	Types of Exercise:	Frequency:
If you are currently sedentary, when did you last exercise?	How many years?	Duration:
	Types of Exercise:	Frequency:
Weight History:		
If overweight, how long have you been overweight?	Were you overweight as a child?	By how much?
	How many times has your weight changed?	
Any events that led up to your obesity? (E.g. Pregnancy, injury) Yes No		If yes, how may events? 1 2 3 4 5 >5
Sleep History:		
Have you ever been diagnosed with a sleep disorder?	Yes	No
Do you use CPAP/BIPAP at night?	Yes	No
Do you snore at night?	Yes	No
Has someone ever told you that you snore at night?	Yes	No
Do you have daytime sleepiness?	Yes	No
Women Only:		
Menstrual history: Age begin____________	Regular? ☐ Yes ☐ No	
☐ Heavy ☐ Medium ☐ Light		
If your periods are irregular or associated with excessive bleeding or unusual discharge please elaborate:		
Number of days between periods:________days	Usual duration of period:________days	
At what age did menopause occur, if applicable?		
Number of pregnancies?_______Number of births?_______Explain any complications with pregnancy: ______________ Are you currently Pregnant?_____		

	Authorization to Release Information - Please check all that applies and sign/date.
☐	**I authorize Appalachian State University to collect and save the above protected health information on me for purposes of research. I understand that all information is private and confidential.**
☐	**I authorize Appalachian State University to keep this information and any information gained from my participation in their studies in a database so that they may contact me.**
☐	**The above information is correct and complete to the best of my knowledge.**

Signature **Date**

Appendix F

24-hour Health History Form:

24-HOUR HEALTH HISTORY

Study: **VTG** **YOB:** ____________ **Height:** ____________ **Weight:** ____________ **Sex:** ____________

Subject Number: ______________________________ **Date:** ______________

Do you have:	**Yes**	**No**	**How do you feel?**		
Head cold	☐	☐		**# of hours sleep**_______	**# of hours since eating:**_________ **What did you eat?**
Nasal Congestion	☐	☐			
Headache	☐	☐	Good	**How was your sleep?**	______________________________
Sore Throat	☐	☐			______________________________
Digestive Upset	☐	☐	Fair	Normal	______________________________
Intestinal Disorder	☐	☐			______________________________
General Fatigue	☐	☐	Not so good	Wakeful	______________________________
Muscle Soreness	☐	☐			
			Bad	Restless	
Medicine taken in last 24 hours: ______________________ ______________________ ______________________ ______________________			**Any leg cramps Since last activity?** **Yes** ☐ **No** ☐	**Physical activity in last 24 hours:** ______________________________ ______________________________ ______________________________ ______________________________	**Any unusual physical activity in last 24 hours?** ______________________________ ______________________________ ______________________________ ______________________________

**** Take weight with each visit.**

24-HOUR HEALTH HISTORY

Study: **VTG** **YOB:** ____________ **Height:** ____________ **Weight:** ____________ **Sex:** ____________

Subject Number: _______________________________ **Date:** ______________

Do you have:	**Yes**	**No**	**How do you feel?**	**# of hours sleep**_______	**# of hours since eating:**_________
Head cold	☐	☐			**What did you eat?**
Nasal Congestion	☐	☐	Good	**How was your sleep?**	________________________________
Headache	☐	☐	Fair	Normal	________________________________
Sore Throat	☐	☐	Not so good	Wakeful	________________________________
Digestive Upset	☐	☐	Bad	Restless	________________________________
Intestinal Disorder	☐	☐			________________________________
General Fatigue	☐	☐			
Muscle Soreness	☐	☐			
Medicine taken in last 24 hours: ________________________ ________________________ ________________________ ________________________			**Any leg cramps Since last activity?** **Yes** ☐ **No** ☐	**Physical activity in last 24 hours:** ___________________________________ ___________________________________ ___________________________________ ___________________________________	**Any unusual physical activity in last 24 hours?** ________________________________ ________________________________ ________________________________ ________________________________

**** Take weight with each visit.**

Last Menstrual Period (LMP): __________________________
(1st Day of LMP)

Vita

Jayvaughn Trujillo-Oliver was born in Longmont, Colorado, to Ricky Oliver and Stephanie Trujillo. He graduated from Athens Drive High school in August 2013. The following autumn, he was accepted to Appalachian State University to study Exercise Science. In May 2017, he was awarded a Bachelor of Exercise Science Degree. For the next 2 years he worked under Dr. Jonathon Stickford as a graduate research assistant studying for his Masters of Exercise Science. The Masters of Exercise Science degree was awarded to him in December 2019.

Mr. Oliver continues to follow his passion to serve underserved communities and is now striving to become a Doctor of Osteopathic Medicine. He resides in Clayton, NC, where he is actively pursuing his passion.